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Scientific review article

AI as a Decision Support Tool in Prostate Cancer Diagnosis: A Literature Review and Trend Analysis

Santiago Salimbeni[1]
Santiago Nicolet[2]

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Abstract: *Advances in AI (AI) have greatly enhanced prostate cancer diagnosis (PCaD). This systematic review (2022–2025) evaluates recent developments, techniques, and the effectiveness of AI-based decision support tools. Convolutional neural networks and generative adversarial networks (GANs) are the most prevalent methods, applied to MRI image classification, lesion detection, segmentation, and image enhancement. These approaches improve lesion localisation, diagnostic precision, and consistency among radiologists and pathologists, while multi-modal systems help reduce unnecessary interventions. Despite progress, key challenges include data heterogeneity, limited model generalisability, and lack of interpretability. Future directions highlight AI-driven risk stratification, streamlined MRI protocols, and integrated imaging pathways. Overall, AI offers promising tools for earlier detection and more personalised, efficient, and patient-centred management of prostate cancer.*

1. INTRODUCTION

Prostate cancer (PCa) is a leading cause of morbidity and mortality in men, with early and accurate diagnosis essential for effective treatment. Traditional methods like PSA testing, biopsy, and Gleason grading have limitations, including invasiveness and inter-observer variability. AI, ML, and DL have emerged as transformative tools to improve diagnostic accuracy, automate workflows, and personalize patient care. This systematic review analyzes 25 studies from 2022–2025 on AI applications in PCa diagnosis, focusing on integration with imaging and clinical data. Key findings indicate that CNNs and advanced DL architectures, including ResNet variants, dominate MRI classification, lesion detection, and segmentation tasks. Transfer learning mitigates limited imaging data, while GANs enhance images and radiomics provides quantitative insights. AI tools improve early PCa detection, reduce Gleason score variability, and enhance lesion localization. Multi-task and multi-modal systems combining histopathology, MRI, and clinical data offer comprehensive diagnostic profiles and may reduce unnecessary biopsies. Explainability methods, such as pixel-level overlays, aid clinical interpretability. The review emphasizes domain-agnostic training, active learning, and the need for large-scale, multicentre validation to ensure robustness and regulatory readiness. Future directions include personalized risk stratification, shorter MRI protocols, integration of imaging with non-imaging biomarkers, and comprehensive AI-driven workflows to enhance diagnostic accuracy, reduce invasiveness, and support patient-centered care. This article is organized as follows: Section 2 presents the methodology and search strategy. Section 3 outlines the results. Section 4 discusses the findings and finally, the conclusions are provided in Section 5.

[1] University of Salvador, Institute for Research in Art, Architecture and Technology, Rodriguez Peña 770, 1114, Autonomous City of Buenos Aires, Argentina

[2] University of Salvador, Institute for Research in Art, Architecture and Technology, Rodriguez Peña 770, 1114, Autonomous City of Buenos Aires, Argentina

2. METHODOLOGY

Researchers conducted a literature search on online databases in June 2025. The database used was Scopus. Titles and keywords with various combinations were used.

To establish a comprehensive overview of existing methods for ML as a Decision Support Tool in Prostate Cancer Diagnosis, an extensive literature review was conducted using the Scopus database. A structured search strategy was employed to identify relevant literature.

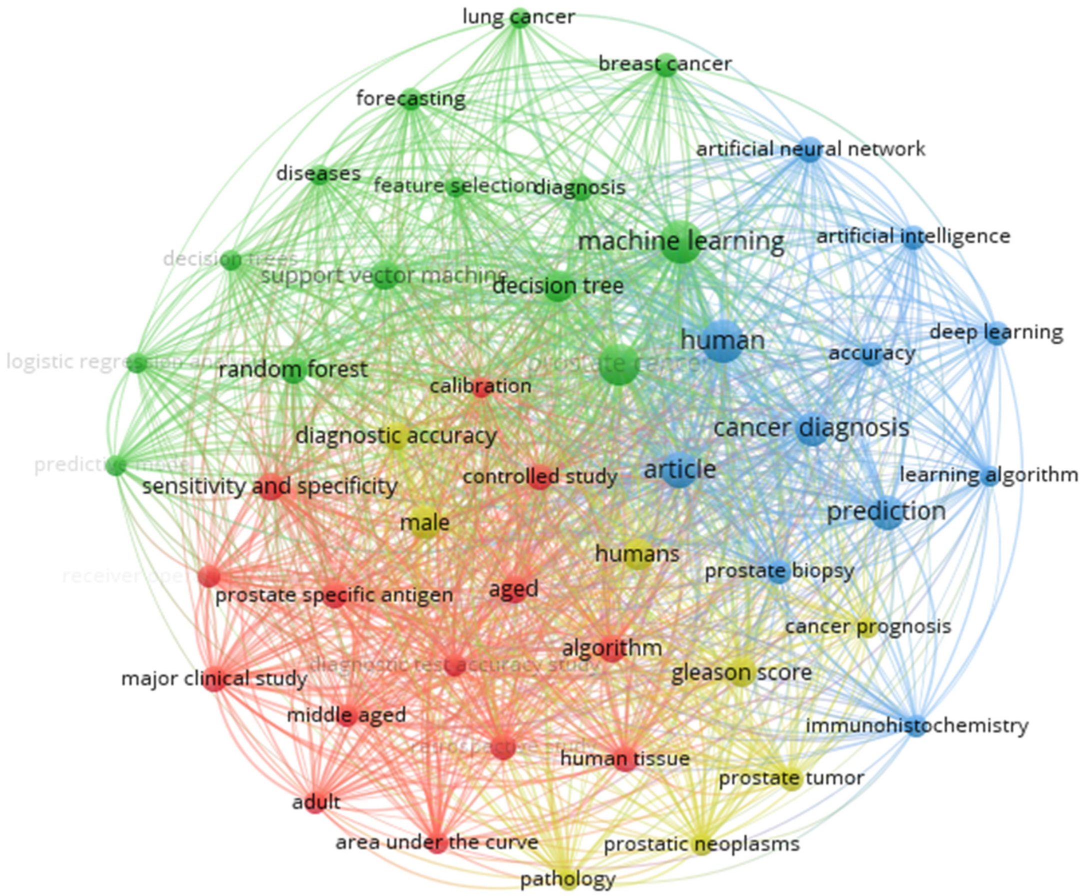

Figure 1. Keyword co-occurrence network in AI-based prostate cancer diagnosis literature (2022–2025)

Source: Own research

In the search within "Article title", the initial query used the keywords: ("prostate cancer" AND "AI" OR "ML" OR "DL") to capture a wide range of articles related to cancer and ML in medicine. To refine the selection, the filter for the years 2022–2025 was applied, resulting in 616 documents. To further narrow the results, the keyword "Imag*" was added, significantly reducing the number of hits to 66 papers. Then, the terms AND Segmentation OR Detection OR Classification OR Analysis OR Diagnosis were added, yielding 57 works. Finally, only articles and conference papers were selected, resulting in a total of 44 articles. After reading the abstracts of those 44 articles, only those aligned with the focus of this study were selected, see Table 1. Twelve articles were excluded. In addition to the database search, snowballing techniques, both backward and forward, were applied to identify further relevant studies. A limited manual search in selected journals and key authors' works was also conducted to ensure comprehensiveness. Then, another 6 articles were added. After reading the full articles, two were excluded.

Table 1. Summary of each article screened

AUTHOR	YEAR	TITLE
Ayyad et al.	2025	Multimodality imaging in prostate cancer diagnosis using AI
Bouslimi et al.	2023	DL-based Detection, Segmentation of PCa from mp-MRI Images.
Das et al.	2024	Intravoxel incoherent motion and diffusion kurtosis imaging and their machine-learning-based texture analysis for detection and assessment of PCa severity at 3 T.
de Rooij et al.	2022	Risk Stratification and AI in Early Magnetic Resonance Imaging–based Detection of PCa.
Gaudiano et al.	2023	An Apparent Diffusion Coefficient-Based ML Model Can Improve PCaD in the Grey Area of the Prostate Imaging Reporting and Data System Category 3
Harder et al.	2024	Enhancing PCaD: AI-Driven Virtual Biopsy for Optimal Magnetic Resonance Imaging
Horasan & Güneş	2024	Advancing Prostate Cancer Diagnosis: A DL Approach for Enhanced Detection in MRI Images.
Jin et al.	2024	T2-weighted imaging-based DL method for noninvasive prostate cancer detection and Gleason grade prediction
Kawula et al.	2023	Prior knowledge based DL auto-segmentation in magnetic resonance imaging-guided radiotherapy of prostate cancer
Kshirsagar et al.	2025	Mitigating Algorithmic Bias in PCa Risk Stratification with responsible AI and ML
Liu et al.	2025	DL network enhances imaging quality of low-b-value diffusion–weighted imaging and improves lesion detection in prostate cancer
Long et al.	2025	Improved PCaD: upgraded prostate imaging reporting and data system (PI-RADS) scores by zoomed diffusion-weighted imaging enhance deep-learning-based computer-aided diagnosis accuracy.
Ma et al.	2022	Texture analysis based on PI-RADS 45-scored magnetic
Matsuoka et al.	2023	DL prostate cancer detection and segmentation on biparametric versus multiparametric magnetic resonance imaging
Mehmood et al.	2023	A classifier model for prostate cancer diagnosis using CNNs and transfer learning with multi-parametric MRI.
Michaely et al.	2022	Current Value of Biparametric Prostate MRI with ML or DL in the Detection, Grading, and Characterization of Prostate Cancer
Pellicer-Valero et al.	2022	DL for fully automatic detection, segmentation, and Gleason grade estimation of prostate cancer in multiparametric magnetic resonance images.
Prata et al.	2023	Radiomic ML Analysis of Multiparametric Magnetic Resonance Imaging in the Diagnosis of Clinically Significant PCa
Raza et al.	2023	A bibliometric analysis of using ML and AI in prostate cancer detection
Rovera et al.	2023	ML CT-Based Automatic Nodal Segmentation and PET Semi-Quantification of Intraoperative 68Ga-PSMA-11 PET/CT Images in High-Risk Prostate Cancer: A Pilot Study
Sihotang et al.	2023	Accuracy of ML models using ultrasound images in prostate cancer diagnosis: a systematic review
Singhal et al.	2022	A DL system for prostate cancer diagnosis and grading in whole slide images of core needle biopsies.
Yang et al.	2023	Equilibrium Optimization Algorithm with DL Enabled Prostate Cancer Detection on MRI Images.
Zhou	2025	Integrating multimodal imaging and peritumoural features for enhanced prostate cancer diagnosis: A ML approach

Source: Own research

3. RESULTS

AI and ML/DL technologies are revolutionising prostate cancer (PCa) diagnosis and management by integrating imaging and clinical data to improve accuracy, reduce invasiveness, and enable personalised care. Their applications have evolved from image enhancement to lesion detection, data integration, and pathological validation, underscoring their clinical value. MRI is central to non-invasive PCa diagnosis, with AI-driven CAD systems enhancing radiologist performance and diagnostic precision. DL, particularly CNNs, outperforms traditional ML in segmentation, lesion localisation, and Gleason grading. Techniques such as CNNs, GANs, radiomics, and NAFNet advance automation and predictive modelling, while transfer learning mitigates data scarcity. Radiomics from ADC and T2-weighted MRI support tissue differentiation, and DL-based systems improve PI-RADS scoring and early detection. Multiparametric MRI combining DWI and DCE enables AI-based tumour assessment and personalised therapy planning. Recent research also explores adversarial robustness to ensure clinical reliability.

3.1. Current Applications of AI, ML, and DL in Prostate Cancer Research:

a. *MRI Image Analysis and Lesion Detection:* DL models, particularly two-dimensional and three-dimensional convolutional neural networks (CNNs and 3D CNNs), have become foundational for analysing multiparametric MRI (mpMRI) scans (Horasan & Güneş, 2024). These networks automatically identify, localize, and segment prostate lesions by learning spatial and volumetric features such as tissue heterogeneity, lesion morphology, and diffusion characteristics. Advanced 3D CNN architectures ingest volumetric mpMRI data (e.g., T2-weighted, diffusion-weighted, ADC maps) to capture contextual tumour information across slices, markedly improving diagnostic accuracy, sensitivity, and specificity compared to manual or 2D approaches (Horasan & Güneş, 2024).

b. *Prostate Cancer Grading and Quantification:* AI-powered histopathology platforms apply DL techniques to whole-slide images to estimate Gleason scores, an essential prognostic marker of tumour aggressiveness (Gavade et al., 2023). By segmenting glandular structures, quantifying architectural patterns, and analysing nuclear atypia, these systems produce reproducible Gleason grade group (GGG) predictions. Automated grading reduces inter-observer variability among pathologists and accelerates workflow, facilitating consistent, objective assessments that align with clinical guidelines (Gavade et al., 2023).

c. *Multimodal Data Integration:* Beyond imaging alone, contemporary AI research integrates mpMRI data with biopsy histology, blood-based biomarkers, and genomic profiles to construct holistic disease models (Horasan & Güneş, 2024). Multimodal fusion approaches, ranging from feature-level concatenation to sophisticated attention-based architectures, enable the correlation of imaging phenotypes with molecular subtypes and treatment response predictors. Such integrative frameworks improve risk stratification and support personalized treatment planning (Horasan & Güneş, 2024).

d. *Explainable AI (XAI):* To promote clinical trust and regulatory acceptance, explainable AI techniques are embedded within DL systems to elucidate decision rationale (Bouslimi et al., 2023). Methods such as saliency mapping, class-activation mapping (CAM), and layer-wise relevance propagation visualize the regions and features driving a model's classification or grading output. XAI not only addresses the "black box" concern but also facilitates error analysis and model refinement in collaboration with clinicians (Bouslimi et al., 2023).

e. *Standardization of PI-RADS Scoring:* ML algorithms contribute to the harmonization of the Prostate Imaging-Reporting and Data System (PI-RADS) by providing quantitative, reproducible criteria for category assignment (Harder et al., 2024). Automated PI-RADS scoring pipelines extract radiomic and deep-learning–derived biomarkers (e.g., texture, shape, diffusion metrics) to standardize lesion characterization, reduce inter-reader variability, and improve diagnostic consistency across imaging centres (Harder et al., 2024).

f. *Computer-Aided Diagnosis (CAD) Systems:* DL-based CAD platforms harness CNNs and hybrid architectures (e.g., Residual Networks, InceptionNet, LSTM-CNN hybrids) to assist radiologists in lesion detection and classification on mpMRI (Bouslimi et al., 2023). By flagging suspicious regions and proposing PI-RADS scores, these systems reduce interpretation time and inter-reader discrepancies. Specific models such as XmasNet and RMANet have demonstrated area under the ROC curve (AUC) values up to 0.99–1.00 for distinguishing benign from malignant lesions on public mpMRI datasets (Bouslimi et al., 2023).

g. *Lesion Segmentation:* U-Net and its variants (e.g., MultiResU-Net) remain the gold standard for pixel-level segmentation of prostate gland and tumour regions on MRI. MultiResU-Net employs multiscale convolutional blocks and residual connections to handle variable lesion sizes and image resolutions, outperforming classical U-Net and other segmentation networks like SegNet in both accuracy and robustness (Bouslimi et al., 2023).

h. *Gleason Grade Group Estimation & Tumour Aggressiveness:* Several studies deploy end-to-end DL pipelines that combine lesion segmentation with classification heads to predict Gleason grade groups directly from mpMRI. By learning radiomic signatures of aggressiveness (e.g., cellular density, microarchitecture), these models aim to noninvasively estimate tumour grade prior to biopsy, supporting targeted sampling and personalized management (Pellicer-Valero et al., 2022).

i. *Feature Extraction & Multi-Modal Fusion:* Advanced DL frameworks utilize multi-channel inputs (e.g., T2-weighted, ADC, Ktrans) either as separate branches or fused at intermediate layers to enhance lesion detectability and segmentation accuracy. Autoencoder modules and attention mechanisms further distil salient features across modalities, improving robustness to imaging variations and facilitating better generalization across institutions (Pellicer-Valero et al., 2022).

j. *Adversarial Robustness:* Research into adversarial deep neural networks highlights vulnerabilities in medical imaging AI systems, small, imperceptible perturbations can induce misclassification. Consequently, studies focus on adversarial training, input denoising, and certified defences to harden prostate cancer models against malicious or accidental perturbations, ensuring safe clinical deployment (Long et al., 2025).

k. *Automated Clinical Workflow Integration:* End-to-end automated pipelines are under development to unify detection, segmentation, grading, and reporting within a single framework. These integrated systems triage cases, prioritize urgent findings, and generate structured reports, streamlining radiology workflows, reducing missed lesions, and accelerating time-to-diagnosis in busy clinical settings (Pellicer-Valero et al., 2022).

3.2. Evaluating the Effectiveness of AI, ML, and DL Tools in Early Prostate Cancer Detection and Reducing Variability in Gleason Scoring:

(Michaely et al. 2022) note that AI, ML, and DL greatly enhance early prostate cancer detection and reduce variability in Gleason scoring, often matching or surpassing expert radiologists, though broader standardization and multicenter validation are still required. Similarly, (Mehmood et al. 2023) highlight that these tools improve diagnostic accuracy, provide objective grading, and address data limitations via transfer learning, contributing to more efficient workflows. (Li et al. 2022) add that DL models trained with precise whole-mount histopathology boost early detection accuracy and consistency among radiologists, serving as both diagnostic and educational tools. (Singhal et al. 2022) confirm AI, ML, and DL effectiveness in early diagnosis and reducing observer variability. Improved Diagnostic Accuracy: Studies report excellent AUCs (~0.976–0.990) for cancer vs. benign classification on large datasets. Raciti (2020) showed Paige Prostate Alpha increased detection sensitivity from 74% to 90%, particularly for lower Gleason grades. Ström (2019) achieved an AUC of 0.960 on extensive biopsy data, demonstrating DL's superior performance. Reduced Gleason Grading Variability: (Nagpal 2020) DL algorithm achieved high agreement with expert consensus (κ_{quad} = 0.92–0.96), outperforming traditional methods. Mun (2021)

YAAGGS model reached 77.5% accuracy and $\kappa = 0.65$ for grade group prediction. Pixel-level overlays and gland segmentation improved interpretability and aligned AI outputs with pathologists' reasoning, reducing subjectivity and variability in prostate cancer assessment.

3.3. Future Directions and Technological Integrations for Advancing Non-Invasive and Accurate Diagnosis of Clinically Significant Prostate Cancer:

The rapid progress of AI, ML, and DL is redefining non-invasive prostate cancer (PCa) diagnostics, shifting toward integrated, multimodal, and clinically deployable systems. Future research focuses on merging clinical, imaging, histopathological, serological, and genomic data into unified diagnostic models to improve accuracy and minimize invasive biopsies (Raza et al., 2023; Kshirsagar et al., 2025). Raza et al. (2023) and Kshirsagar et al. (2025) highlight multi-modal AI/ML models that combine PSA levels, radiomics, mpMRI, genomic and patient-reported data, using advanced segmentation and data fusion to detect subtle patterns of clinically significant PCa (csPCa). Michaely et al. (2022) emphasize creating standardized multicenter datasets, improving MRI acquisition consistency, and developing advanced DL architectures beyond CNNs for better lesion segmentation and risk stratification. Integrating radiomics and genomics with AI could enhance personalized risk assessment, while commercial AI tools and automation will democratize high-quality diagnosis and reduce clinician workload. Mehmood et al. (2023) reinforce that progress in AI architectures, imaging, CAD systems, and data standardization is driving accuracy and non-invasive diagnostics. Li et al. (2022) confirm DL tools' benefits in improving early detection and reducing inter-observer variability using whole-mount histopathology for both diagnostics and training. Maarten de Rooij et al. (2022) point to risk-based patient selection, shorter MRI protocols (bpMRI), and AI-driven automation across workflows—from risk assessment to staging and treatment planning. AI can accelerate MRI acquisition and act as a second reader, enhancing diagnostic consistency and supporting personalized therapy through integration of imaging and non-imaging biomarkers. Singhal et al. (2022) envision multi-task, multi-modal AI systems that combine histopathology, MRI, ultrasound, and clinical data for comprehensive diagnostics, integrating long-term clinical outcomes for improved prognostics. He also highlights domain-agnostic training, explainable AI, and workflow automation to boost interpretability, efficiency, and scalability. Across studies, the consensus is clear: future PCa diagnostics will rely on integrative, explainable, and validated AI systems that combine diverse data sources, automate key diagnostic tasks, standardize imaging, and personalize patient management - ultimately achieving more accurate, efficient, and equitable prostate cancer care.

4. CONCLUSION

The SLR highlights the transformative role of AI, ML, and DL in prostate cancer (PCa) diagnosis and management. Between 2022 and 2025, AI has evolved from experimental tools to essential clinical components, enhancing diagnostic accuracy, efficiency, and personalisation. Technological Advancements and AI Architectures: Modern AI models such as CNNs, GANs, and NAFNet have markedly improved prostate MRI segmentation, lesion localisation, Gleason grading, and image enhancement (Liu et al., 2025). These DL methods outperform traditional ML by automatically extracting complex features, increasing sensitivity and specificity in detecting clinically significant PCa. Clinical Performance and Diagnostic Impact: DL models using transfer learning with pretrained networks like ResNet excel in distinguishing benign from malignant lesions and in PI-RADS classification (Liu et al., 2025). AI enhances early PCa detection and reduces inter-observer variability, improving diagnostic consistency. Multi-modal AI integrating imaging, histopathological, and clinical data shows potential to lower biopsy rates and limit invasiveness (Zhou et al., 2025). Integration Into Clinical Workflows: AI systems act as decision-support tools and second readers, assisting radiologists and pathologists by flagging suspicious areas and providing objective assessments (Long et al., 2025). Pixel-level overlay maps improve interpretability, while automation in reporting, biopsy planning, and treatment stratification streamlines workflows. Future Directions: Promising areas include AI-driven risk calculators integrating PSA and biomarkers for targeted imaging, AI-facilitated abbreviated MRI (bpMRI) maintaining accuracy with reduced scan time (Liu et al., 2025), and unified predictive frameworks combining imaging, histopathology, and biomarkers for personalised management (Jin et al., 2024). Challenges: Key issues include data diversity, multi-centre validation, interpretability, clinician trust, and regulatory integration (Zhou et al., 2025). Overall, AI, ML, and DL are reshaping PCa diagnosis by enhancing detection, localisation, and patient-specific assessment. Continued advances in architectures, data integration, and validation will further enable personalised, efficient, and minimally invasive AI-assisted PCa care, confirming AI as an indispensable clinical ally (Long et al., 2025).

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