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REVIEW

Artificial Intelligence as a Diagnostic Tool for Benign Prostatic Hyperplasia (BPH): A Narrative Review

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Background: Benign prostatic hyperplasia (BPH) is a highly prevalent condition among aging men and represents a significant clinical and economic burden. Current diagnostic approaches, including prostate-specific antigen (PSA) testing and imaging modalities, remain limited by low specificity, false-positive findings, and variability in interpretation, particularly in differentiating BPH from prostate cancer.

Objective: This narrative review aims to evaluate the role of artificial intelligence (AI) as a diagnostic tool for BPH, focusing on its performance, clinical applications, and potential to address current diagnostic limitations.

Methods: A narrative review was conducted using PubMed, Scopus, and ScienceDirect. The search strategy included studies published between 2021 and 2025 using keywords such as ("benign prostatic hyperplasia" OR "BPH") AND ("artificial intelligence" OR "machine learning" OR "deep learning"). A total of 10 studies meeting predefined inclusion criteria were analyzed, focusing on diagnostic applications of AI in urology.

Results: AI-based models demonstrated promising performance across multiple diagnostic domains, including imaging (mpMRI, ultrasound), histopathology, and biomarker-based analysis. Several studies demonstrated improved diagnostic accuracy and reduced interobserver variability compared to conventional methods. AI also showed potential in differentiating BPH from prostate cancer and supporting clinical decision-making. However, significant challenges remain, including heterogeneity of datasets, limited external validation, potential algorithmic bias, and lack of standardized evaluation frameworks.

Conclusion: Artificial intelligence represents a promising adjunct in the diagnosis of BPH, with the potential to enhance diagnostic accuracy and optimize clinical workflows. Nevertheless, further high-quality studies, standardized validation, and integration into real-world clinical settings are required before widespread clinical adoption can be achieved.

Keywords: benign prostatic hyperplasia, artificial intelligence, machine learning, deep learning, radiomics, clinical decision support

Introduction

Benign prostatic hyperplasia (BPH) is one of the most common urological conditions affecting aging men, with prevalence exceeding 50% in individuals over the age of 60 and reaching up to 90% in aged populations.[1]

The condition is a major contributor to lower urinary tract symptoms (LUTS), significantly impairing quality of life and imposing a substantial burden on healthcare systems due to increasing prevalence and associated management costs.[1] Despite advances in diagnostic strategies, current approaches to BPH remain unsatisfactory.

Prostate-specific antigen (PSA), although extensively used, lacks sufficient specificity, particularly in the presence of inflammation or overlapping pathological conditions.[1] Additionally, imaging modalities such as multiparametric magnetic resonance imaging (mpMRI) may produce false-positive findings due to similarities between BPH and prostate cancer (PCa), complicating clinical decision-making.[2] In addition, interobserver variability in imaging interpretation further limits individual reliability and consistency.

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Artificial intelligence (AI), encompassing machine learning (ML) and deep learning (DL) techniques, has emerged as a transformative tool in medical diagnostics. AI systems are capable of analyzing large and complex datasets, enhancing diagnostic accuracy, reducing interobserver variability, and enhancing clinical decision-making processes.[3,4]

In urology, AI applications have demonstrated promising results in imaging analysis, histopathological assessment, and predictive modeling, offering the potential to overcome numerous limitations of traditional diagnostic techniques.[5] However, despite the rapid expansion of AI research, its application in BPH remains incompletely established. Current literature is characterized by heterogeneity in study design, limited external validation, and deficient integration into real-world clinical workflows.[5] Moreover, existing reviews frequently concentrate on specific AI modalities or lack emphasis on translational challenges, making it difficult to assess the true clinical applicability of these technologies.

Therefore, this narrative review aims to provide an updated synthesis of recent evidence (2021–2025) on the role of artificial intelligence as a diagnostic tool for BPH. This review specifically focuses on diagnostic performance, crucial limitations, and the major translational challenges that must be addressed to facilitate the safe and effective integration of AI into clinical practice. Importantly, it aims to bridge the gap between current AI research and real-world clinical implementation in BPH diagnosis.

Methods

This study represents a narrative review aimed at synthesizing current evidence on the use of artificial intelligence (AI) as a diagnostic tool for benign prostatic hyperplasia (BPH).

A comprehensive literature search was conducted using PubMed, Scopus, and ScienceDirect databases. The search strategy incorporated predefined keywords and Boolean operators as follows: ("benign prostatic hyperplasia" OR "BPH") AND ("artificial intelligence" OR "machine learning" OR "deep learning" OR "radiomics").

Studies published between 2021 and 2025 in the English language were considered. The initial search yielded multiple relevant studies, which were screened based on titles and abstracts. After removal of duplicates and irrelevant articles, full-text assessment was performed, resulting in the inclusion of 10 studies that met the predefined criteria.

Inclusion criteria were defined as: (1) studies addressing diagnostic or predictive applications of AI in BPH; (2) studies reporting measurable outcomes such as accuracy, sensitivity, specificity, or area under the curve (AUC); and (3) peer-reviewed articles. Exclusion criteria included editorials, conference abstracts, non-urological AI applications, studies lacking diagnostic outcomes, and duplicate publications.

A total of 10 studies met the inclusion criteria and were included in the final analysis.

Data extraction was performed manually, focusing on study characteristics, type of AI model, sample size, diagnostic performance metrics, and reported limitations.

As this study is a narrative review, no formal risk of bias assessment or meta-analysis was conducted. Instead, a descriptive synthesis of the findings was performed to highlight emerging trends, strengths, limitations, and translational challenges in AI-based BPH diagnostics.

Results

Imaging-Based Artificial Intelligence

Radiomics and deep learning are two of the most widely investigated AI techniques in the diagnostic review of BPH. Radiomics consists of the extraction of large sets of quantitative features from medical images, which portray subtle tissue heterogeneity beyond human visual perception due to texture, shape, and signal intensity. These methods allow automated and reproducible image interpretation when coupled with deep learning algorithms like CNNs. Recent studies using mpMRI have demonstrated promising diagnostic performance in differentiating BPH from prostate cancer. For example, deep learning models such as convolutional neural networks have demonstrated promising performance, achieving high AUC values compared to conventional radiomics approaches.[5]

Similarly, in classifying BPH from malignancy, CNNs trained with TRUS images have demonstrated high diagnostic performance, with some studies reporting accuracies of up to 99.77%, along with sensitivity of 99.8% and specificity of 99.77%.[5]

AI-based models have demonstrated promising diagnostic performance, with reported accuracies reaching up to 96.3% using deep learning–based computer vision systems compared to approximately 90% with traditional machine learning approaches such as fuzzy logic models.[6]

Other radiomics-based approaches predicted IHC markers such as P504s and P63 with an AUC of 0.92, suggesting the feasibility of non-invasive tissue phenotype prediction. Despite such strong results, the majority of studies remain retrospective and single-center, limiting external validity.

Overall, these findings suggest that deep learning approaches may provide improved diagnostic performance compared to conventional machine learning methods, although further validation is required.

Histopathology and Digital Pathology

Digital pathology applies AI algorithms to microscopic images of tissue, trying to standardize and accelerate histological diagnosis. Architectures like Mask R-CNN coupled with ResNet have been able to automatically detect and classify benign versus malignant glandular structures using CNN models. These models achieved diagnostic accuracies of over 95% in discriminating BPH from carcinoma during recent studies.[2,4]

Serum-and Spectroscopy-Based AI Models

Going beyond imaging, AI has been applied to biochemical and spectroscopic data to achieve minimally invasive diagnostics. The serum biomarkers, especially the pattern of immunoglobulin N-glycans that were used in training machine-learning classifiers, showed high specificity (approximately 90%), in identifying BPH and distinguishing it from other urological disorders. Likewise, CNNs trained on Raman spectroscopy signals combined with patient age and prostate-specific antigen (PSA) values attained an AUC of 0.91 and overall accuracy of 0.866.[5] These findings highlight the potential of AI to derive diagnostic insights from blood samples, yet multicenter prospective validation remains lacking.

Expert and Decision-Support Systems

There are expert systems and AI applications based on fuzzy logic, which help in the evaluation process of BPH based on symptoms. Based on the results of the International Prostate Symptom Score questionnaires and other clinical data, algorithms determine disease severity and recommended therapies. In the evaluation studies, the agreement rates of fuzzy-logic decision systems were about 90% with the evaluation of urologists.[5] These can help decrease variations between healthcare providers and improve patient triaging processes, and this decreases the need for healthcare specialists.

Outcome Prediction and Clinical Workflow Optimization

Apart from diagnostic tasks, ML algorithms have been applied to predict the outcome of treatments and the post-operative period. The predictive models for the improvement in urinary flow (Qmax) and symptoms (IPSS) scores after surgical or pharmacological management resulted in the attainment of AUC values between 0.67 and 0.73.[7] The integration of AI has also been considered in optimizing urologic processes, handling physician shortages, and efficiently making decisions.[8]

Discussion

Artificial intelligence could bring promising improvements in diagnostic studies of benign prostatic hyperplasia.[5] AI has been shown to enhance diagnostic accuracy and reduce interobserver variability across imaging and pathology, supporting its role as a clinical decision-support tool rather than a replacement for clinicians.[9] Despite encouraging accuracies reported in imaging, histopathology, and serum-based studies, several methodological and practical limitations hamper its translation into clinical routine. Despite the promising performance reported in the included studies, many AI applications remain in early-stage or research settings with limited real-world clinical integration. Major strengths and limitations of AI in the diagnostics of BPH are discussed parallel to challenges in its implementation and future directions.

Strengths and Advantages of AI-Based Diagnostics

The key strength of AI applications in BPH is to extract and analyze complex, multidimensional data beyond human perception. Objectivity in the quantification of subtle textural and morphological features on multimodal mpMRI and TRUS imaging is provided by radiomics and deep learning models. Indeed, this has been extensively discussed.[5]

These techniques have the potential to lower the diagnostic subjectivity arising from visual interpretation and thus improve reproducibility among centers. In this way, machine learning classifiers of biochemical or spectroscopic signatures could perform the non-invasive differentiation of BPH from prostate cancer, which avoids unnecessary biopsies.[5] Clinical data and symptom scores entered into AI-driven decision-support systems may also serve to standardize treatment recommendations, improve efficiency and support clinical workflow. Put together, these developments show how AI can add to the diagnostic process in a more precise and data-driven way, thus helping in personalized patient management.

Limitations and Methodological Constraints

While several performance metrics appear promising, current studies on AI in BPH face important methodological limitations. Despite these promising results, current AI applications in BPH remain limited by poor generalizability and lack of widespread clinical implementation.[6] Many studies highlight the lack of external validation and standardized evaluation frameworks, which may limit generalizability and real-world applicability.[5]

Another important aspect is data heterogeneity, as differences in imaging protocols, equipment settings, and patient demographics may strongly influence model performance.[3]

Another limitation is the lack of transparency and interpretability. Deep learning models often behave as "black boxes," providing limited insight into how decisions are derived, which may reduce clinicians' trust and hinder regulatory approval.[3,10]

Finally, the lack of standardization in reporting performance metrics, preprocessing steps, and dataset characteristics makes it challenging to compare various studies or replicate results across different research groups.[2,5] Ethical, Regulatory, and Bias Challenges.

There are several ethical and regulatory issues related to the use of AI in BPH diagnostics. The training algorithms using patient data raise ethical issues of data privacy, informed consent, and ownership. Much greater transparency in data governance and adherence to existing privacy laws-including, but not limited to, the EU's General Data Protection Regulation-are vitally important.[4] From a regulatory perspective, relatively few AI-based diagnostic tools have received regulatory approval (eg, FDA or CE marking). Approval of medical AI has to be given after strong clinical validation of clear benefits, coupled with post-market monitoring-areas wherein current models on BPH are wanting.[4,5]

Lack of standardization as far as auditing algorithm frameworks is concerned postpones the formal certification and adoption of algorithms across health systems.[2]

Another major ethical risk is bias within data sets. Where models have been pre-trained on restricted, homogeneous data-represented by geography, age, or ethnicity-they tend to perform poorly or are unfair on under-represented groups. This means that any future datasets should focus on diversity, balance, and transparency in labeling so that diagnostic performance is equitable for all patient populations.[4,10]

Future Directions

The future should be aimed at multi-center, prospective validation with uniform imaging and clinical protocols to facilitate clinical translation. It would be necessary to test the generalizability and robustness of different models across cohorts of patients. They should also adhere in a transparent way to reporting guidelines, such as TRIPOD-AI or CONSORT-AI, so as to make their work more reproducible and comparable by their peers.[2] The integration of multi-modal AI systems comprising imaging, biochemical, and clinical data may, therefore, achieve superior diagnostic performances compared to single-domain model counterparts.[7] Finally, integrating AI into routine workflows will require collaboration between clinicians, engineers, and regulatory agencies in ensuring these technologies are safe, reliable, and clinically effective.

Overall Interpretation

Although AI technologies have great potential for transforming diagnosis and management in BPH, they are not yet ready for general clinical use.[5] The current findings support AI as a valuable adjunct to, rather than a replacement for clinician expertise. Ongoing efforts at validation, transparency, and ethical regulation will be crucial if AI-based diagnostics are to transition from experimental tools to trusted components of urological practice.[4]

Conclusion

Artificial intelligence has the potential to significantly enhance the diagnosis of benign prostatic hyperplasia by improving accuracy, objectivity, and data-driven clinical decision-making. However, several challenges continue to limit widespread clinical implementation, including limited external validation, dataset heterogeneity, and regulatory and ethical concerns.

Future research should focus on large-scale, multicenter validation, the development of explainable AI models, and the integration of multimodal data.

Overall, AI holds significant promise in enhancing BPH diagnostics by improving diagnostic accuracy, reducing unnecessary biopsies and invasive procedures, and supporting more efficient clinical decision-making. However, its successful clinical adoption will depend on rigorous validation, standardization, and integration into real-world health-care systems.

Disclosure

The author reports no conflicts of interest in this work.

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