BRAIN. Broad Research in Artificial Intelligence and Neuroscience
e-ISSN: 2067-3957 | p-ISSN: 2068-0473
Covered in: Web of Science (ESCI); EBSCO; JERIH PLUS (hkdir.no); IndexCopernicus; Google Scholar; SHERPA/RoMEO; ArticleReach Direct; WorldCat; CrossRef; Peeref; Bridge of Knowledge (mostwiedzy.pl); abcdindex.com; Editage; Ingenta Connect Publication; OALib; scite.ai; Scholar9; Scientific and Technical Information Portal; FID Move; ADVANCED SCIENCES INDEX (European Science Evaluation Center, neredataltics.org); ivySCI; exaly.com; Journal Selector Tool (letpub.com); Citefactor.org; fatcat!; ZDB catalogue; Catalogue SUDOC (abes.fr); OpenAlex; Wikidata; The ISSN Portal; Socolar; KVK-Volltitel (kit.edu)
2024, Volume 15, Issue 4, pages: 319-324.
Submitted: August 7th, 2024 | *Accepted for publication:* November 19th, 2024

Artificial Intelligence in Urology: New Technologies with Major Potential

Bogdan Novac
Department of Urology, "Dr. C.I. Parhon" Hospital, Iași, Romania;
Faculty of Medicine, University of Medicine and Pharmacy "Grigore T. Popa", 16 Universității Street, 700115, Iași, Romania.
https://orcid.org/0000-0003-4501-1718

Radu Zara*
Department of Urology, "Dr. C.I. Parhon" Hospital, Iași, Romania
zara.radu00@gmail.com

Alin Ciobica
Department of Biology, Faculty of Biology, Alexandru Ioan Cuza University of Iași, Carol I Avenue, No. 20A, 700506, Iași, Romania;
Center of Biomedical Research, Romanian Academy, Iași Branch, Teodor Codrescu Street 2, 700481, Iași, Romania;
Academy of Romanian Scientists, 3 Ilfov Street, 050044, Bucharest, Romania
″Ioan Haulică″ Institute, Apollonia; University, Păcurari Street 11, 700511, Iași, Romania.

**Corresponding Author*

Abstract: *The present paper described how Artificial intelligence (AI) is revolutionizing urology, with applications in diagnosis, treatment planning, and patient monitoring. This review highlights AI's role in key urological areas, such as cancer detection, robotic-assisted surgeries, and personalized patient care. These advancements significantly enhance clinical decision-making and treatment outcomes. Thus, we can clearly state that AI has immense potential to redefine urological practice, fostering accuracy, efficiency, and patient-centered care. However, the integration of these technologies requires addressing challenges like data security, ethical concerns, and regulatory validation. Future efforts should focus on developing robust, evidence-based AI tools to ensure their safe and effective deployment in clinical settings.*

Keywords: *urology; artifical inteligence; machine learning; deep learning; artificial neural networks; computer vision; natural language processing; benign prostatic hypetrophy; urodinamic studies; bladder cancer; carcinoma of the prostate; renal cancer.*

How to cite: Novac, B., Zara, R., & Cobica, A. (2024). Artificial intelligence in urology: New technologies with major potential. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience, 15*(4), 319-324. https://doi.org/10.70594/brain/15.4/21

©2024 Published by EduSoft Publishing. This is an open-access article under the CC BY-NC-ND license

1. Introduction

Artificial intelligence (AI) technologies have been developing fulminatingly in recent times, especially in the medical field, helping in the diagnosis, monitoring, and treatment of many conditions. Through deep learning algorithms and machine learning, AI offers increased accuracy in cancer detection, robotic-assisted surgery planning, and continuous patient monitoring. This review explores applications of AI in urology, addressing its role in optimising clinical decisions and personalising treatment, directly impacting the quality of care and patient outcomes.

2. Materials and methods

The search strategy was adjusted to identify and analyse the literature on the use of artificial intelligence in urology. Keywords such as 'urology', 'artificial intelligence', 'machine learning', 'deep learning', 'artificial neural networks', 'computer vision', and 'natural language processing' were used and the results were categorised accordingly. Review articles, editorial comments, and studies outside the field of urology were excluded.

3. Introduction to artificial intelligence

Artificial intelligence is the ability of machines to perform human cognitive tasks, bringing a new paradigm to healthcare and clinical decision-making. Big data generated by modern technologies such as electronic health records supports AI in creating useful predictive models to improve patient care. By 2025, AI in healthcare is projected to grow by 29.3% annually, with global revenues increasing by 40%, shifting the medical system towards outpatient clinics and preventive medicine.

AI comprises four broad sub-domains applicable in healthcare: (figure 1)

1. **Machine Learning (ML):** uses statistical techniques to learn and recognise patterns, enabling the generation of human-like outcomes.
2. **Natural Language Processing (NLP):** supports medical document analysis, language translation, and speech recognition to provide virtual assistance to physicians.
3. **Deep Learning (DL) and Artificial Neural Networks (ANNs):** multi-layer networks enable detailed identification of complex patterns in images.
4. **Computer vision:** facilitates tumor identification and analysis of radiological and pathological images.

AI is increasingly being used in the diagnosis and management of urological conditions in areas such as urolithiasis, benign prostatic hypertrophy, uro-oncology, urodynamics, and robotically assisted surgery. This article explores the application of AI in urologic subspecialties (Figure 1).

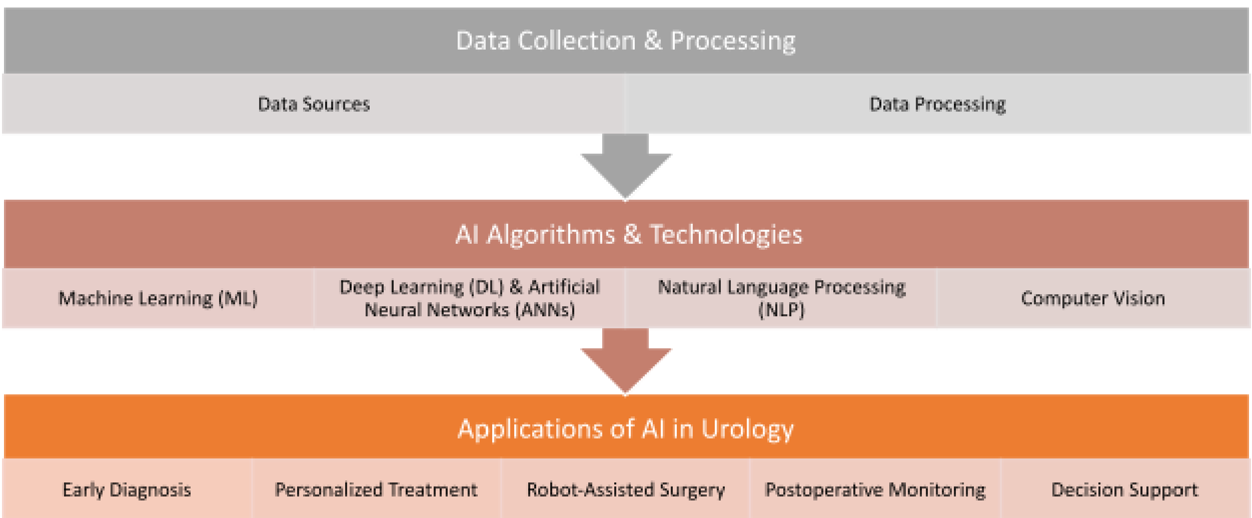

Figure 1. Practical applicability of AI technologies

4. Urolithiasis and artificial intelligence in diagnosis and treatment

In recent decades, the treatment and monitoring of urolithiasis has evolved significantly, with AI now being used to identify kidney stones from CT and ultrasound images, determine their composition, predict spontaneous clearance, and predict the outcome of endourological procedures. A convolutional neural network (CNN) was created on CT images from 535 patients, achieving over 90% accuracy in stone detection, concluding that the efficiency of CNNs can be increased by transferable learning and augmented datasets (Parakh et al., 2019, Black et al., 2020). An ML-based algorithm developed for outcome prediction after percutaneous nephrolithotomy (PCNL) in 146 patients achieved up to 95% accuracy, comparable to standard nomograms (Aminsharifi et al., 2020). Another ML-based decision support system, trained on data from 254 patients, has also been described, with an accuracy of 94.8% in predicting surgical outcomes, 85.2% in determining the need for ureteral stent insertion, and 95% for the need for transfusion. (Shabaniyan et al., 2019) These technologies suggest promising applicability of AI in the management and optimization of urolithiasis treatment.

5. Benign prostatic hypertrophy

Diagnosis and prediction of clinical response to treatment in benign prostatic hypertrophy: A system described by Bukhari et al, (2020) based on computer vision specialised for histopathological evaluation of prostatic tissue and diagnosis of hyperplasia of the glandular component of the prostate gland that achieved a diagnostic accuracy of 96.3% (f1-score). The results suggest that artificial intelligence can become an essential tool in histopathological diagnosis, reducing human error. (Bukhari et al., 2020) Another study explores the application of intelligent fuzzy systems in diagnosing the level of severity and recommending appropriate therapies for benign prostatic hyperplasia (BPH) patients. The system captures different factors through two modules: the first one determines the level of severity of BPH, and the second one modulates treatment decisions using an ontology model and a type-1 fuzzy system. The efficiency and accuracy of the system were validated in a study with 44 participants, comparing the results with the recommendations of a panel of experts and statistically analysing their accuracy which reached up to 90% (Torshizi et al., 2014).

6. Urodynamic studies

The interpretation of urodynamic study results using a machine learning-based automated diagnostic system for preliminary analysis of urodynamic studies applied to lower urinary tract dysfunction (LUTD) was described. The study included eight common LUTD conditions with 527 eligible patients from 2015-2020. Two global parameters (age and sex of patients) and 13 urodynamic parameters were used as input for the algorithms. Three machine learning methods were applied and evaluated: Decision Tree (DT), Logistic Regression (LR), and Support Vector Machine (SVM). The best models obtained a mean AUC of 0.90, suggesting significant potential in improving LUTD diagnosis (Ding et al., 2024).

7. Bladder cancer

Standard white light cystoscopy (WLC) is the primary diagnostic method for bladder carcinoma, with a sensitivity of 62-84% and a specificity of 43-98%, depending on the investigator. To improve detection, techniques such as Hexaminolevulinate (HAL) fluorescence-assisted transurethral resection (HAL)-assisted transurethral resection and the use of narrow-band imaging (NBI) have been developed (Daneshmand et al., 2018) ML algorithms, DCNN models, genetic algorithms, and SVMs have been applied in bladder cancer to improve cystoscopic diagnosis and prognosis and survival prediction Ikeda et al. realised a competent CNN by training it with 2102 cystoscopic images to increase the efficiency of bladder cancer diagnosis using AI. It achieved a sensitivity and specificity of 89.7% and 94.0%, respectively (Ikeda et al., 2020).

Ali et al., (2021) created an AI-based software that recognises and predicts the histological stage of bladder tumors, with a sensitivity of 96% and specificity of 89%. In addition, the model predicted tumor invasion (T1 and T2) with 100% and 91% accuracies (Ali et al., 2021). In molecular classification, another AI model created by Woerl et al. (2020) recognised tumor subtypes with 89% accuracy on histopathological preparations, improving pathology experts' diagnosis from 38.2% to 58.9%. These innovations suggest that AI could bring major advances in the molecular diagnosis and classification of urothelial carcinoma (Woerl et al., 2020).

8. Carcinoma of the prostate

AI applications are poised to revolutionise current practice in prostate carcinoma in terms of diagnosis, treatment decisions, and even prediction of disease-free survival. To improve the diagnosis of prostate cancer, various radiologic techniques have been developed. Although computed tomography (CT) is generally considered insufficient for soft tissue characterization, a study by Koreevaar et al. demonstrated that a new artificial intelligence-based application can effectively detect prostate cancer with 88% accuracy. This highlights the potential of CT imaging in identifying clinically significant cancers (Korevaar et al., 2021).

Furthermore, the variability of the PI-RADS score depending on the radiologist's experience can be significantly reduced by AI-assisted workflows, increasing the diagnostic accuracy from 84% to 88% according to the study by Winkel et al. (2021).

There is a large observer-dependent variability in Gleason classification due to the subjective nature of analysing biopsy specimens. With this in mind, Ström et al. (2020) developed an AI model for prostate cancer identification, Gleason classification, and localisation. The model was trained with 6682 digitised slides from 976 men and tested on 1631 biopsy specimens from 246 men. It achieved an accuracy of 0.997 (AUC) to differentiate between a malignant and a benign tumor. The results in terms of Gleason classification were also comparable to those obtained by expert pathologists (Ström et al., 2020). AI-based technologies are also used intra-operatively, where they contribute to automatic laparoscopic camera positioning and tissue recognition, increasing patient safety and the efficiency of robotic operations. An AI model developed by Porpiglia et al. (2019) allows intraoperative detection of extracapsular enlargement during radical prostatectomy, providing real-time 3D images. This technique may also aid in partial renal resections, improving organ preservation rates. (Porpiglia et al., 2019). And another study presented the development of an advanced computer vision algorithm aimed at automatically labeling surgical steps in videos of robotic-assisted radical prostatectomy.

The research team performed a detailed manual annotation of 474 surgical videos by specialists under the supervision of urologic oncologists to identify all stages of the surgery. The algorithm was trained on a dataset of 292 cases, and the results showed a 92.8% agreement between the automated artificial intelligence-based analysis and the human labels. The accuracy of the algorithm was maximal for the vesico-urethral anastomosis stage (97.3%) and minimal for the final inspection and extraction stage (76.8%). This innovation has important applications in surgeons' video review, surgical training, quality and safety assurance, and operating room logistics. (Khanna et al., 2024)

9. Renal cancer

The imaging distinction between benign oncocytoma and renal cell carcinoma can be difficult because of their similar features, especially for the chromophobe variant of renal cell carcinoma, which is difficult to differentiate histologically from oncocytoma. Recently, a radiological method that allows 100% accuracy in this differentiation has been validated, based on the measurement of contrast enhancement in tumors compared to adjacent tissue. However, the method requires manual localization of the area of maximal contrast, making it subjective and limited. As an automated alternative, Baghdadi et al. (2020) developed an artificial intelligence-based software using CT images that distinguishes with 100% sensitivity and 89% specificity these two tumor types. Only one case out of 20 was not correctly classified, probably due to a small tumor size (1.4 cm). With extended data and optimization, these models can support a radiological diagnosis of renal tumors (Baghdadi et al., 2020).

In addition, biomarkers based on gene expression have been developed to predict ccRCC survival and prognosis. For example, Li et al. created a model based on 15 genes that showed a correlation between higher risk and poorer prognosis. (Li et al., 2018)

On the other hand, Kocak et al. (2019) used ANN algorithms to identify PBRM1 mutations in CT textures with 88% accuracy. This approach may help in the development of non-invasive biomarkers for prognosis and treatment (Kocak et al., 2019).

10. Conclusion

The use of artificial intelligence in urology may mark a transformative period, with many applications already developed and many in the pipeline. AI has the potential to improve clinical care, patient education, and treatment outcomes, as well as streamline daily tasks. However, as we explore this field, it is essential to consider ethical issues, data security concerns, and the need for rigorous validation of these AI tools.

Abbreviations

AI - Artificial intelligence
ANNs - artificial neural networks
AUC - area under the curve
BPH - benign prostatic hyperplasia
ccRCC - clear cell renal cell carcinoma
CNN - convolution neural network
CT - computed tomography
DCNN - Deep neural convolution network
DL - Deep learning
DT - Decision Tree
HAL - Blue light cystoscopy with hexaminolevulinate
LR - Logistic Regression
LUTD - lower urinary tract dysfunction
ML - Machine learning
NLP - Natural language processing
PCNL - percutaneous nephrolithotomy
SVM - Support Vector Machine
WLC - white light cystoscopy

References

Ali, N., Bolenz, C., Todenhöfer, T., et al. (2021). Deep learning-based classification of blue light cystoscopy imaging during transurethral resection of bladder tumors. *Scientific Reports, 11*(1), 11629. https://doi.org/10.1038/s41598-021-91081-x

Aminsharifi, A., Irani, D., Tayebi, S., Jafari Kafash, T., Shabanian, T., & Parsaei, H. (2020). Predicting the postoperative outcome of percutaneous nephrolithotomy with machine learning system: Software validation and comparative analysis with Guy's Stone Score and the CROES Nomogram. *Journal of Endourology, 34*(6), 692-699. https://doi.org/10.1089/end.2019.0475

Baghdadi, A., Aldhaam, N. A., Elsayed, A. S., et al. (2020). Automated differentiation of benign renal oncocytoma and chromophobe renal cell carcinoma on computed tomography using deep learning. *BJU International, 125*(4), 553-560. https://doi.org/10.1111/bju.14985

Black, K. M., Law, H., Aldoukhi, A., Deng, J., & Ghani, K. R. (2020). Deep learning computer vision algorithm for detecting kidney stone composition. *BJU International, 125*(6), 920-924. https://doi.org/10.1111/bju.15035

Bukhari, S. U., Syed, A., & Sajid, S. (2020). Machine learning approaches for the histopathological diagnosis of prostatic hyperplasia. *Annals of Clinical and Analytical Medicine, 11*, Article 20105. https://doi.org/10.4328/ACAM.20105

Daneshmand, S., Bazargani, S. T., Bivalacqua, T. J., et al. (2018). Blue light cystoscopy for the diagnosis of bladder cancer: Results from the US prospective multicenter registry. *Urologic Oncology, 36*(8), 361.e1-361.e6. https://doi.org/10.1016/j.urolonc.2018.04.013

Ding, Z., Zhang, W., Wang, H., et al. (2024). An automatic diagnostic system for the urodynamic study applying in lower urinary tract dysfunction. *International Urology and Nephrology, 56*(2), 441-449. https://doi.org/10.1007/s11255-023-03795-8

Ikeda, A., Nosato, H., Kochi, Y., et al. (2020). Support system of cystoscopic diagnosis for bladder cancer based on artificial intelligence. *Journal of Endourology, 34*(3), 352-358. https://doi.org/10.1089/end.2019.0509

Khanna, A., Antolin, A., Bar, O., et al. (2024). Automated identification of key steps in robotic-assisted radical prostatectomy using artificial intelligence. *Journal of Urology, 211*(4), 575-584. https://doi.org/10.1097/JU.0000000000003845

Kocak, B., Durmaz, E. S., Ates, E., & Ulusan, M. B. (2019). Radiogenomics in clear cell renal cell carcinoma: Machine learning-based high-dimensional quantitative CT texture analysis in predicting PBRM1 mutation status. *AJR American Journal of Roentgenology, 212*(3), W55-W63. https://doi.org/10.2214/AJR.18.20443

Korevaar, S., Tennakoon, R., Page, M., et al. (2021). Incidental detection of prostate cancer with computed tomography scans. *Scientific Reports, 11*(1), 7956. https://doi.org/10.1038/s41598-021-86972-y

Li, P., Ren, H., Zhang, Y., & Zhou, Z. (2018). Fifteen-gene expression based model predicts the survival of clear cell renal cell carcinoma. *Medicine (Baltimore), 97*(33), e11839. https://doi.org/10.1097/MD.0000000000011839

Parakh, A., Lee, H., Lee, J. H., Eisner, B. H., Sahani, D. V., & Do, S. (2019). Urinary stone detection on CT images using deep convolutional neural networks: Evaluation of model performance and generalization. *Radiology: Artificial Intelligence, 1*(4), e180066. https://doi.org/10.1148/ryai.2019180066

Porpiglia, F., Checcucci, E., Amparore, D., et al. (2019). Augmented-reality robot-assisted radical prostatectomy using hyper-accuracy three-dimensional reconstruction (HA3D™) technology: A radiological and pathological study. *BJU International, 123*(5), 834-845. https://doi.org/10.1111/bju.14549

Shabaniyan, T., Parsaei, H., Aminsharifi, A., Shabanian, T., & Rahmanian, S. (2019). An artificial intelligence-based clinical decision support system for large kidney stone treatment. *Australasian Physical & Engineering Sciences in Medicine, 42*(3), 771-779. https://doi.org/10.1007/s13246-019-00780-3

Ström, P., Kartasalo, K., Olsson, H., Gawad, S., Sjöblom, P., & Eklund, M. (2020). Artificial intelligence for diagnosis and grading of prostate cancer in biopsies: A population-based, diagnostic study. *Lancet Oncology, 21*(2), 222-232. https://doi.org/10.1016/S1470-2045(19)30738-7

Torshizi, A. D., Zarandi, M. H., Torshizi, G. D., & Eghbali, K. (2014). A hybrid fuzzy-ontology based intelligent system to determine level of severity and treatment recommendation for benign prostatic hyperplasia. *Computers in Biology and Medicine, 113*, 301-313. https://doi.org/10.1016/j.cmpb.2013.09.021

Winkel, D. J., Tong, A., Lou, B., Funderburk, D., Mendenhall, D., Harris, S., & Silva, R. (2021). A novel deep learning based computer-aided diagnosis system improves the accuracy and efficiency of radiologists in reading biparametric magnetic resonance images of the prostate: Results of a multireader, multicase study. *Investigative Radiology, 56*(10), 605-613. https://doi.org/10.1097/RLI.0000000000000780

Woerl, A. C., Eckstein, M., Geiger, J., Mosbah, A., Westhoff, N., Vogt, T., & Kranzbühler, H. (2020). Deep learning predicts molecular subtype of muscle-invasive bladder cancer from conventional histopathological slides. *European Urology, 78*(2), 256-264. https://doi.org/10.1016/j.eururo.2020.04.023