OPEN ACCESS Freely available online

Andrology-Open Access

Review Article

The Research Progress of Artificial Intelligence in the Diagnosis of Urogenital Tumors

Mengying Zhu[1,2], Xiaoquan Yang[1], Zhenzhu Zhai[1,2], Fang Chen[3], Ruibin Liu[1,2], Guohua Zhao[1], Yue Wang[1*]

[1]Department of General Surgery, Cancer Hospital of China Medical University, Liaoning Cancer Hospital and Institute, Shenyang, China; [2]Department of General Surgery, Liaoning University of Traditional Chinese Medicine, Shenyang, China, Shenyang, China; [3]Department of Gynecology, People's Hospital of Liaoning Province, Shenyang, China

ABSTRACT

In recent years, the incidence of urological cancers, particularly Bladder Cancer (BC), Renal Cell Carcinoma (RCC) and Prostate Cancer (PCa), has significantly increased, highlighting the critical importance of early detection and timely treatment in improving patient outcomes. The often asymptomatic nature of these tumors in their early stages frequently leads to diagnoses at advanced stages, which adversely affects treatment efficacy and survival rates. The diagnosis of urological tumors relies on medical imaging, pathological slides and endoscopic images, all of which are essential for early detection but face limitations such as physician subjectivity and time-consuming analysis. The advent of Artificial Intelligence (AI) presents a promising solution for extracting features from tumor images that may be difficult to identify visually, thereby enhancing diagnostic accuracy. This is particularly advantageous in cases of poor imaging quality or when physicians have limited experience, as AI can provide more accurate pathological information. This article explores the vital role of AI in the early diagnosis of urological tumors, demonstrating how it assists physicians in identifying early signs through the analysis of medical images and data. By improving diagnostic accuracy and efficiency, AI not only enhances patient prognosis but also supports the development of personalized treatment plans, thus advancing the field of urology.

Keywords: Artificial intelligence; Bladder cancer; Renal cell carcinoma; Prostate cancer; Diagnosis

INTRODUCTION

AI is a branch of computer science focused on researching and developing theories, methods and technologies to simulate and improve human intelligence [1]. Its core objective is to create systems capable of perceiving their environment and executing a variety of tasks. Key technologies include Machine Learning (ML) and Deep Learning (DL). ML is a subfield of AI focused on developing algorithms and models that enable computers to learn from data and make predictions or decisions [2]. DL is a more complex branch of ML that utilizes artificial neural networks to process and analyze data. It extracts high-level features from data through multi-layered network structures, making it suitable for handling complex tasks such as image, audio and text processing [3]. ML and DL have made significant strides in the diagnosis of urological tumors, fundamentally transforming how healthcare professionals approach this critical area of medicine. One of the most impactful innovations is the application of Convolutional Neural Networks (CNNs) in medical imaging, which excel at analyzing complex visual data [4]. By leveraging these advanced algorithms, clinicians can significantly enhance diagnostic accuracy. Additionally, these technologies rapidly process large volumes of data, enabling the identification of intricate patterns that may be undetectable to the human eye [5]. This capability enables clinicians to make more reliable recommendations, ultimately fostering the development of personalized treatment plans tailored to the specific needs of each patient.

Correspondence to: Yue Wang, Department of Gynecology, People's Hospital of Liaoning Province, Shenyang, China; E-mail: wangyue1@cancerhosp-ln-cmu.com

Received: 01-Oct-2024, Manuscript No. ANO-24-34411; **Editor assigned:** 04-Oct-2024, PreQC No. ANO-24-34411 (PQ); **Reviewed:** 18-Oct-2024, QC No. ano-24-34132; **Revised:** 13-Oct-2025, Manuscript No. ANO-24-34411 (R); **Published:** 20-Oct-2025, DOI: 10.35248/2167-0250.25.14.363

Citation: Zhu M, Yang X, Zhai Z, Chen F, Liu R, Zhao G, et al. (2025) The Research Progress of Artificial Intelligence in the Diagnosis of Urogenital Tumors. Andrology. 14:363.

LITERATURE REVIEW

Research progress of AI in BC diagnosis

Initially, diagnostic cystoscopy was one of the most frequently employed techniques for detecting BC, particularly in cases of hematuria [6]. However, in recent years, DL has shown significant promise in the diagnosis of BC. Lorencin, et al. [7] proposed a BC diagnosis method combining a multilayer perceptron with a Laplacian edge detector to integrate simpler methods with DL techniques. Using a dataset of 1,997 BC images and 986 non-cancerous images, the results showed that the multilayer perceptron achieved an AUC of 0.99 after preprocessing, with optimal performance for image sizes of 50 × 50 and 100 × 100 pixels. The Ikeda team created a tumor classifier using 2,102 cystoscopic images with CNNs. Testing showed 78 true positives from 87 tumor images and 315 true negatives from 335 normal images, resulting in 20 false positives and 9 false negatives. The ROC curve area was 0.98, with sensitivity of 89.7% and specificity of 94.0%. This study demonstrates that CNN effectively classifies cystoscopic images, improving BC diagnosis and treatment accuracy [8]. Accurate staging of BC is crucial for selecting the appropriate treatment plan for patients. Xu et al. [9] proposed a non-invasive pre-operative differentiation strategy for BC, analyzing 62 cases of T2-weighted MRI and extracting Volume of Interest (VOI). They used RFE-SVM to select 29 optimal features, achieving an accuracy of 88.7% in distinguishing BC from bladder wall tissue. The study indicated that 3D texture analysis based on MRI significantly outperformed 2D texture analysis. Garapati, et al. [10] developed a ML-based system for staging BC, classifying cases as ≥ T2 or below T2. The Automatic Initialization Cascaded Level Set (AI-CALS) method was used to segment 84 lesions and extract morphological and texture features, followed by two-fold cross-validation. LDA, neural networks, SVM and random forest classifiers were employed for scoring, with all four models achieving an Area Under the ROC Curve (AUC) of over 0.88. Woerl, et al. utilized 423 digital slides of tumor samples to develop, validate and evaluate a DL model. The findings indicated that the model excelled in predicting MIBC molecular subtypes based solely on HE slides, with performance matching or surpassing that of experts, while also uncovering significant new histopathological characteristics. Chen, et al. developed an automatic diagnostic and prognostic model for BC based on histopathological data, achieving AUCs of 96.3%, 89.2% and 94.1% in training, testing and external validation, respectively and effectively distinguishing BC from glandular cystitis (AUC 93.4%). In summary, the application of AI technology in the diagnosis of BC demonstrates significant potential, including tumor detection, histopathological staging, molecular subtype identification and patient prognosis assessment. These advancements provide effective support for clinical decision-making and hold promise for further improving treatment outcomes and prognoses for BC patients.

DISCUSSION

Research progress of AI in RCC diagnosis

In clinical practice, the benign or malignant nature of renal cell tumors is a key prognostic factor affecting patient survival and treatment. Xi, et al. collected preoperative MR images of 1,162 renal lesions for a multicenter cohort study, dividing the images into training, validation and test sets. Of these lesions, 655 were classified as malignant and 507 as benign. The ensemble deep learning model outperformed the baseline zero-rule algorithm, expert averages and the radiomics model in test accuracy, sensitivity and specificity. Oberai, et al. created a CNN classifier that utilizes multiphase Contrast-Enhanced CT (CECT) images for the diagnosis of solid-enhancing malignant renal masses, achieving an accuracy of 78%, a sensitivity of 70% and an AUC of 0.82. The pathological types of RCC include clear cell RCC (ccRCC), chromophobe RCC (chRCC), papillary RCC (pRCC), collecting duct carcinoma and undifferentiated carcinoma. These different subtypes show significant variations in treatment and prognosis, affecting patient survival rates and disease progression. Zhang and his team performed a CT texture analysis on 100 cases of ccRCC and 27 cases of non-clear cell RCC (non-ccRCC). By employing a model that included Standard Deviation (SD), entropy, Mean Pixel Intensity (MPP) and kurtosis, they achieved an AUC of 0.94 for distinguishing non-ccRCC from ccRCC, along with an accuracy of 87%. In comparison, a model that included SD, MPP and skewness produced an AUC of 0.96, but achieved an accuracy of only 78% in distinguishing the two types. Nie, et al. developed a CT-based DL Radiomics Model (DLRM) to predict the SSIGN score of localized ccRCC. The study included 784 patients and the model combined radiomic features with DL features, evaluated by AUC for performance. The results indicated that DLRM outperformed traditional methods in predicting both the SSIGN score and Cancer-Specific Survival (CSS), with micro-average AUCs of 0.913 and 0.969 for the test cohorts, respectively and a superior C-index as well. Accurately delineating tumor boundaries on CT images is of utmost guiding significance for kidney partial nephrectomy. This precise segmentation not only helps surgeons clearly identify the specific location and size of the tumor, but also effectively assesses the involvement of surrounding tissues, allowing for the development of a more rational surgical plan. Yu, et al. proposed Crossbar-Net, a cascaded trainable segmentation model designed to focus on difficult-to-segment regions of tumors. When tested on a real CT kidney tumor dataset containing 3,500 slices, this approach surpassed leading segmentation techniques based on metrics such as the Dice similarity coefficient, true positive rate, centroid distance and Hausdorff distance. AI shows significant potential in the diagnosis of RCC. Relevant research primarily focuses on tumor classification regarding benign and malignant nature, histopathological subtyping and image segmentation. With continuous advancements in technology, these methods are expected to further improve patient prognosis and survival rates, bringing positive impacts to clinical practice.

Research progress of AI in PCa diagnosis

MRI scanning has become a primary method for detecting PCa, offering detailed insights into the prostate's structure and any potential abnormalities. In recent years, much of the research in this field has focused on leveraging AI technologies to enhance diagnostic accuracy and improve outcomes. Vente, et al. proposed an end-to-end 2D U-Net neural network for the detection and grading of PCa in MRI slices, outputting lesion segmentation maps for the Gleason Grade Groups (GGG). The model achieved a voxel-weighted kappa value of 0.446 and a Dice similarity coefficient of 0.370 through 5-fold cross-validation. On the ProstateX-2 challenge test set, the weighted kappa value for lesions was 0.13. The study demonstrated that this model outperforms traditional multi-class classification and multi-label ordinal regression, while also evaluating various methods to enhance performance. Ishioka, et al. studied data from 335 patients with prostate-specific antigen levels below 20 ng/mL who had MRI and biopsy procedures. They designed a Computer-Aided Diagnosis (CAD) algorithm that leveraged deep CNNs, achieving high accuracy in two evaluation datasets and subsequently validating it on an independent dataset. ROC curve analysis revealed that the CAD system attained over 90% in accuracy, sensitivity and specificity for automating PCa detection using MRI, indicating its potential to improve standardization in clinical practice. The Gleason score is widely regarded as one of the most important prognostic indicators for patients with PCa. This scoring system assesses the differentiation of tumor tissue to help doctors evaluate the aggressiveness of the cancer. Research has shown that AI technology can be combined with pathology slides to effectively predict the Gleason score for PCa. Kott, et al. developed a DL algorithm for tissue pathology diagnosis and Gleason scoring of prostate biopsies, analyzing 85 samples from 25 patients and extracting 14,803 image patches. The model attained an accuracy of 91.5% in distinguishing between benign and malignant cases and 85.4% in the more detailed classification of Gleason scores 3, 4 and 5. Although the performance is good, the study has limitations due to the small sample size and the need for external validation. Overall, the algorithm demonstrates excellent performance in PCa diagnosis. Bulten, et al. created a deep learning system for grading prostate biopsies based on the Gleason grading standard. This system utilizes a semi-automated labeling method and has been validated through agreement among three uropathologists. The system demonstrated high consistency with the reference standard (weighted Cohen's kappa of 0.918) and excelled in distinguishing between benign and malignant cases (area under the curve of 0.990). In observer experiments, the system's scores outperformed those of the expert group and it maintained good consistency in external test datasets (weighted Cohen's kappa of 0.723 and 0.707). In summary, the integration of AI in PCa diagnosis shows promising advancements, particularly in MRI detection and Gleason scoring. Studies demonstrate that AI models can enhance diagnostic accuracy and standardization, outperforming traditional methods. While challenges remain, such as sample size and validation, the potential for AI to improve patient outcomes and clinical practice is significant. Continued research and development in this field could lead to more reliable and efficient diagnostic tools, ultimately benefiting patient care in PCa management.

CONCLUSION

In recent years, the application of AI in the diagnosis of urogenital tumors, particularly BC, RCC and PCa, has shown significant promise. AI technologies such as ML and DL have revolutionized the way medical professionals approach tumor diagnosis by improving the accuracy, efficiency and reliability of imaging analysis. The implementation of AI-driven models, such as CNNs, has enhanced the identification of subtle features in medical images that may otherwise be undetectable to the human eye. This advancement is particularly important given the often asymptomatic nature of these tumors in their early stages, which leads to late diagnoses and diminished treatment outcomes. In the diagnosis of BC, DL methods like CNNs and AI-assisted cystoscopy have shown high sensitivity and specificity in identifying malignant tissues. Studies have demonstrated that AI can effectively distinguish bladder tumors, stage cancers accurately and predict molecular subtypes, all of which are crucial for personalized treatment planning. Similarly, AI has made strides in RCC diagnosis, particularly in distinguishing between benign and malignant tumors using preoperative imaging. The use of DL models has also improved the accuracy of RCC subtyping, which is vital for determining treatment strategies and predicting patient survival. For PCa, AI has been instrumental in enhancing the precision of MRI-based detection and Gleason grading, a key prognostic tool for assessing cancer aggressiveness. AI models have demonstrated high consistency with expert pathologists in grading prostate biopsies, offering a more standardized and efficient approach to diagnosing and staging PCa. By integrating AI into MRI analysis and pathology, clinicians can better detect early-stage tumors and refine treatment strategies.

Despite significant advancements, challenges persist in the widespread clinical adoption of AI technologies. Issues such as limited sample sizes, the necessity for extensive external validation and the complexity of integrating AI tools into clinical workflows present substantial barriers to full-scale implementation. Furthermore, while AI excels in pattern recognition and diagnostic assistance, it cannot entirely replace the expertise of medical professionals. Human oversight remains crucial to ensure that AI-generated findings are interpreted correctly within the broader clinical context. Looking ahead, the potential for AI in the diagnosis of urogenital tumors is immense. As AI algorithms continue to evolve, incorporating larger datasets and more advanced technologies, we can anticipate further improvements in diagnostic accuracy and efficiency. Moreover, the integration of AI with emerging technologies, such as liquid biopsy and genomic profiling, could enhance early detection and enable more personalized treatment options. With ongoing research and development, AI has the potential not only to improve diagnostic practices but also to revolutionize patient care by providing more reliable, timely and precise interventions for urogenital tumors. Ultimately, the future of AI in this field holds great promise, paving the way for enhanced clinical outcomes and improved quality of life for cancer patients.

ACKNOWLEDGMENTS

This work was supported by the National Natural Science Cultivation Foundation of China of Liaoning Cancer Hospital (2021-ZLLH-18); The Natural Science Foundation of Liaoning (2024-MS-266).

CONFLICT OF INTEREST

The authors declare no conflict of financial interests.

AUTHOR'S CONTRIBUTIONS

Mengying Zhu, wrote the manuscript.

Zhenzhu Zhai, Fang Chen, Ruibin Liu, contributed to the Methodology.

Xiaoquan Yang, Guohua Zhao, verified and polished the manuscript.

Yue Wang wrote the manuscript and provide the funding.

REFERENCES

1. He J, Baxter SL, Xu J, Xu J, Zhou X, Zhang K. The practical implementation of artificial intelligence technologies in medicine. Nat Med. 2019;25(1):30-36.
2. Tang R, Zhang S, Ding C, Zhu M, Gao Y. Artificial intelligence in intensive care medicine: Bibliometric analysis. J Med Internet Res. 2022;24(11):e42185.
3. Hinton G. Deep learning a technology with the potential to transform health care. JAMA. 2018;320(11):1101-1102.
4. Li Z, Liu F, Yang W, Peng S, Zhou J. A survey of convolutional neural networks: Analysis, applications and prospects. IEEE Trans Neural Netw Learn Syst. 2022;33(12):6999-7019.
5. Castiglioni I, Rundo L, Codari M, di Leo G, Salvatore C, Interlenghi M, et al. AI applications to medical images: From machine learning to deep learning. Phys Med. 2021;83:9-24.
6. Devlies W, de Jong JJ, Hofmann F, Bruins HM, Zuiverloon TC, Smith EJ, et al. The diagnostic accuracy of cystoscopy for detecting bladder cancer in adults presenting with haematuria: A systematic review from the european association of urology guidelines office. Eur Urol Focus. 2024;10(1):115-122.
7. Lorencin I, Anđelić N, Španjol J, Car Z. Using multi-layer perceptron with Laplacian edge detector for bladder cancer diagnosis. Artif Intell Med. 2020;102:101746.
8. Ikeda A, Nosato H, Kochi Y, Kojima T, Kawai K, Sakanashi H, et al. Support system of cystoscopic diagnosis for bladder cancer based on artificial intelligence. J Endourol. 2020;34(3):352-358.
9. Xu X, Zhang X, Tian Q, Zhang G, Liu Y, Cui G, et al. Three dimensional texture features from intensity and high order derivative maps for the discrimination between bladder tumors and wall tissues *via* MRI. Int J Comput Assist Radiol Surg. 2017;12(4):645-656.
10. 10. Garapati SS, Hadjiiski L, Cha KH, Chan HP, Caoili EM, Cohan RH, et al. Urinary bladder cancer staging in CT urography using machine learning. Med Phys. 2017;44(11):5814-5823.