НИРКИ® KIDNEYS

DOI: https://doi.org/10.22141/2307-1257.13.3.2024.466

Kirolos Eskandar
Diakonie Klinik, Mosbach, Germany

Artificial intelligence in nephrology: revolutionizing diagnosis, treatment, and patient care

For citation: Počki. 2024;13(3):213-219. doi: 10.22141/2307-1257.13.3.2024.466

Abstract. *Artificial intelligence (AI) is rapidly transforming the landscape of nephrology, offering innovative solutions that enhance diagnosis, treatment, and patient care. This literature review explores the current and potential applications of AI across various domains within nephrology. We discuss AI-driven advancements in early diagnosis, personalized treatment planning, renal replacement therapy, and transplant nephrology. Furthermore, we examine how AI enhances patient care through remote monitoring, telehealth, and virtual assistants. While the promise of AI is immense, this review also addresses the ethical, regulatory, and technical challenges that accompany its integration into clinical practice. By highlighting the transformative potential of AI in nephrology, we underscore the need for continued research and collaboration to fully realize its benefits in improving kidney health outcomes.*

Keywords: *artificial intelligence; nephrology; chronic kidney disease; machine learning; personalized medicine*

Introduction

Artificial intelligence (AI) has seen a significant rise in its application across various medical specialties, including nephrology. The integration of AI into medicine marks a transformative shift, enabling healthcare providers to enhance diagnosis, treatment, and patient care. AI encompasses a range of technologies, including machine learning (ML), natural language processing (NLP), and computer vision, which are being leveraged to analyze vast amounts of medical data. These technologies facilitate the early detection of diseases, optimize treatment protocols, and personalize patient care [1, 2].

In healthcare, AI technologies are used in several innovative ways. Machine learning algorithms, for instance, are adept at analyzing complex datasets, which can include patient histories, imaging studies, and genetic information. This capability allows for more accurate predictive analytics, leading to early disease detection and tailored treatment plans. In nephrology, AI is being applied to predict the progression of chronic kidney disease (CKD) and to identify patients at high risk for acute kidney injury (AKI). These applications highlight AI's growing role in improving patient outcomes and reducing healthcare costs [1, 2].

The adoption of AI in medicine also brings about a shift toward what is termed as "augmented medicine", where AI technologies support and enhance the decision-making capabilities of healthcare professionals. This shift is crucial in specialties like nephrology, where complex decisions are made daily regarding patient management. AI systems can assist nephrologists by providing evidence-based recommendations, thus improving the accuracy of diagnoses and the effectiveness of treatments [1].

Despite these advancements, the integration of AI into healthcare faces challenges, including resistance from healthcare providers who may be unprepared for the rapid technological changes. Moreover, ethical concerns, such as data privacy and the potential for AI to replace human judgment, continue to be debated. Nonetheless, the consensus in the medical community is that AI will not replace physicians but will instead augment their capabilities, allowing for more efficient and effective patient care [1, 2].

Methodology

This literature review was conducted using a systematic approach to ensure comprehensive and unbiased coverage of the relevant literature. The review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-

For correspondence: Kirolos Eskandar, Diakonie Klinik Mosbach, Germany; e-mail: kiroloss.eskandar@gmail.com
Full list of author's information is available at the end of the article.

Analyses (PRISMA) guidelines, which facilitated a structured and transparent process for study selection and data extraction.

Search strategy

A thorough literature search was performed across several reputable databases to identify relevant studies and articles on the application of AI in nephrology. The databases used included PubMed, Google Scholar, Scopus, and Web of Science.

The search was conducted using a combination of specific keywords and Medical Subject Headings (MeSH) terms related to the study's focus. The key search terms included "artificial intelligence", "nephrology", "chronic kidney disease", "machine learning", "personalized medicine", "renal replacement therapy" and "transplant nephrology." Boolean operators (AND, OR) were used to combine these terms effectively, and filters were applied to limit results to peer-reviewed articles published in English.

Inclusion and exclusion criteria

The studies were selected based on the following inclusion criteria:

— language: only articles published in English were considered;

— focus: the study must focus specifically on the application of AI in nephrology, including diagnosis, treatment, renal replacement therapy, transplant nephrology, and patient care;

— publication date: preference was given to studies published within the last 10 years to ensure the review reflects the most current research trends;

— study type: original research articles, reviews, meta-analyses, and clinical trials were included.

Exclusion criteria involved:

— non-English publications: articles not published in English were excluded;

— irrelevant focus: studies that did not specifically focus on AI applications in nephrology were excluded;

— duplicate studies: duplicate records across databases were removed.

Study selection process

Initially, 131 articles were retrieved from the databases. After removing duplicates, 105 unique articles remained. These articles underwent a rigorous screening process, which included:

1) title and abstract screening: the titles and abstracts of all identified articles were screened to assess their relevance to the topic. Studies that did not meet the inclusion criteria were excluded at this stage;

2) full-text review: the full texts of the remaining 45 articles were then reviewed to confirm their relevance and adherence to the inclusion criteria. This resulted in 28 studies being included in the final review.

A PRISMA flow diagram (Fig. 1) illustrates the study selection process, showing the number of records identified, screened, and included, along with reasons for exclusion at each stage.

Data extraction and analysis

Data were extracted from the selected studies using a standardized form. The extracted data included:

— study characteristics: authors, year of publication, study design, and population;

— AI application: specific AI techniques used (e.g., machine learning, natural language processing), area of nephrology addressed, and outcomes measured;

— key findings: major results and conclusions of each study, focusing on the effectiveness of AI in improving diagnosis, treatment planning, patient outcomes, and overall nephrology practice.

The extracted data were synthesized to provide a comprehensive overview of the current landscape of AI applications in nephrology, highlighting key trends, challenges, and potential future directions.

Quality assessment

The quality of the included studies was assessed using criteria such as study design, sample size, and methodological rigor. Studies were categorized based on their risk of bias, and only those deemed to have a low to moderate risk of bias were included in the final analysis.

AI in early diagnosis of kidney diseases

The application of AI in the early diagnosis of kidney diseases, particularly CKD, is revolutionizing nephrology by offering unprecedented accuracy and predictive capabilities. ML algorithms are at the forefront of this transformation, providing tools that can predict the onset and progression of CKD with remarkable precision. These algorithms analyze vast amounts of data, including patient demographics, comorbidities, and laboratory results, to identify patterns that may not be immediately apparent to human clinicians [3]. The accuracy of these ML models has been validated in several studies, showing strong potential to improve early detection and intervention strategies, which are critical for preventing the progression of CKD to more severe stages [4].

AI-driven imaging techniques are also making significant strides in the early detection of kidney abnormalities. These techniques utilize advanced image recognition algorithms to analyze radiological images, such as ultrasounds and CT scans, to detect subtle changes in kidney structure that may indicate the early stages of disease [5]. By automating the analysis process, AI reduces the likelihood of human error and enhances the consistency and speed of diagnoses, allowing for earlier intervention and potentially better patient outcomes.

Furthermore, AI is being employed to identify high-risk patients through predictive analytics. By integrating data from various sources, including electronic health records and wearable devices, AI systems can continuously monitor patients and alert healthcare providers to those at greatest risk of developing CKD or experiencing disease progression [6]. This proactive approach enables clinicians to tailor interventions more precisely, potentially reducing the burden of CKD on both patients and healthcare systems.

AI in personalized treatment planning

AI is revolutionizing personalized treatment planning in nephrology by utilizing vast amounts of patient data and genomic information to tailor individualized treatment strategies. These AI-driven approaches involve advanced machine learning algorithms that analyze complex datasets, including electronic health records (EHRs), genetic profiles, and real-time patient data, to predict how patients will respond to specific treatments. This ability to personalize care is particularly crucial in nephrology, where patients often have complex and chronic conditions like CKD that require long-term management.

AI models in nephrology are designed to optimize dialysis treatment by adjusting parameters based on real-time patient data. These predictive models use historical patient data and ongoing monitoring to fine-tune dialysis prescriptions, such as the timing, duration, and intensity of treatments, to improve patient outcomes and reduce complications. For example, AI can predict which patients are at higher risk for complications like intradialytic hypotension, allowing for adjustments to be made in the treatment plan before issues arise [7].

In addition to optimizing dialysis, AI plays a significant role in medication management by analyzing patient histories, genetic data, and current medications to predict and prevent adverse drug reactions (ADRs). This is particularly important in nephrology, where polypharmacy is common due to the complex nature of kidney disease management. AI algorithms can identify potential drug interactions or contraindications that might not be immediately apparent to clinicians, thereby reducing the risk of ADRs and improving patient safety. These systems can also suggest alternative medications or dosages tailored to the patient's unique genetic makeup and disease state [8].

AI's ability to process and analyze large datasets also extends to genomics, where it can identify genetic markers associated with different responses to treatments. This information can then be used to design highly personalized treatment plans that are more effective and have fewer side effects. For instance, AI-driven genomic analysis can help identify patients who are likely to benefit from specific nephroprotective drugs, or who may be at higher risk for certain complications, enabling more targeted and proactive care [9].

Furthermore, AI is instrumental in reducing the burden on healthcare systems by streamlining treatment planning and reducing unnecessary interventions. By accurately predicting patient outcomes and optimizing treatment plans, AI helps in resource allocation, ensuring that patients receive the most appropriate and effective care without the need for trial-and-error approaches. This not only improves patient outcomes but also enhances the efficiency of healthcare delivery in nephrology [9].

AI in renal replacement therapy

AI has become a pivotal force in enhancing renal replacement therapy (RRT), driving significant advancements in both hemodialysis and peritoneal dialysis. AI's role in these therapies is multifaceted, encompassing improvements in the efficiency and personalization of treatment, as well as aiding in the development of next-generation artificial kidneys.

AI-driven innovations in hemodialysis machines are transforming the delivery of this essential treatment. Modern hemodialysis systems equipped with AI algorithms can continuously monitor and adjust dialysis parameters in real-time. These systems analyze vast amounts of patient data, including blood pressure, electrolyte levels, and fluid balance, to optimize the treatment process. By doing so, they help reduce complications such as hypotension and ensure that the dialysis session is tailored to the patient's immediate needs. This level of precision is unattainable through traditional methods, where adjustments are often based on intermittent monitoring and clinical judgment alone [10].

In peritoneal dialysis (PD), AI is playing an equally transformative role. AI systems integrated into PD management are particularly useful for remote patient monitoring. For instance, in Japan, AI-enabled automated peritoneal dialysis (APD) devices allow healthcare providers to monitor patients in real-time, adjusting treatment protocols as

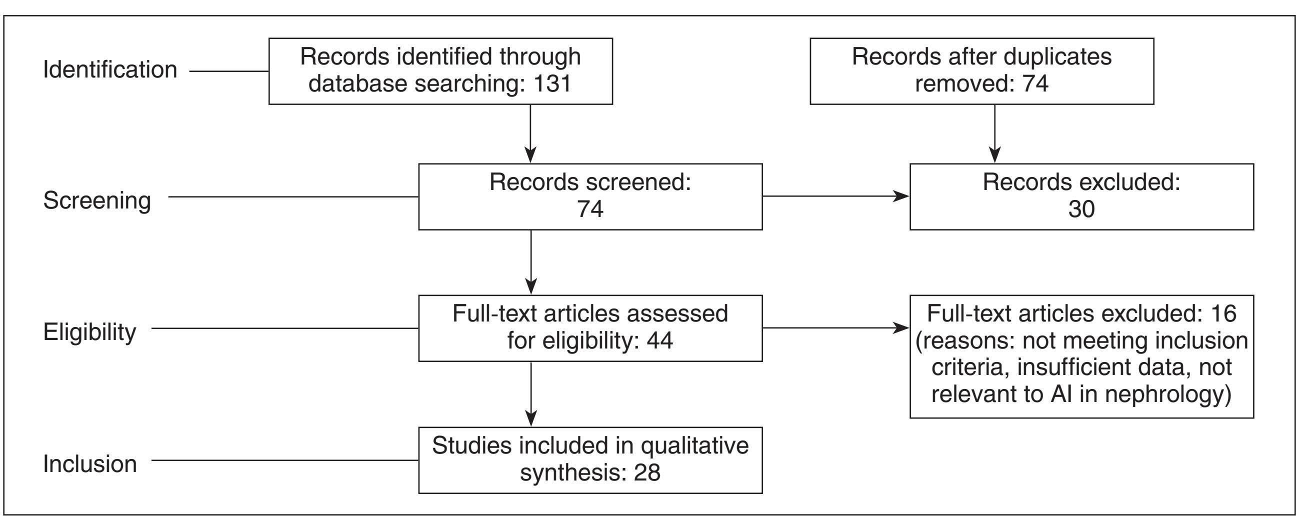

Figure 1. The PRIMSA flow diagram

necessary based on data collected from the patient's home. This approach not only enhances the safety and effectiveness of PD but also improves patient compliance by reducing the need for frequent hospital visits [11]. The use of AI in PD is particularly beneficial for elderly or chronically ill patients who may find frequent travel to healthcare facilities burdensome.

Moreover, AI is at the forefront of efforts to develop artificial kidneys. These next-generation devices aim to replicate the functions of a natural kidney, offering a potential lifeline to patients with end-stage renal disease (ESRD) who are not candidates for traditional dialysis. AI's contribution to this field includes the design and optimization of biocompatible materials, the development of sensors for real-time monitoring of kidney function, and the creation of algorithms that can predict and respond to changes in the patient's condition. These innovations are crucial for the eventual realization of fully functional, implantable artificial kidneys, which could drastically improve the quality of life for patients with ESRD [12].

AI in monitoring and managing CKD progression

AI has significantly advanced the monitoring and management of CKD progression, providing tools that enhance patient care and outcomes. Remote monitoring of kidney function using AI-powered tools is one of the most impactful developments in nephrology. These tools integrate with EHRs and wearable devices, offering continuous, real-time monitoring of patients' health data. AI algorithms analyze this data to track important biomarkers and detect early signs of deterioration, allowing timely interventions. For example, AI systems can monitor estimated glomerular filtration rate (eGFR) and serum creatinine levels, providing alerts when these indicators suggest worsening kidney function. This continuous monitoring can significantly reduce the need for frequent hospital visits, enabling more proactive management of CKD [13].

Predictive analytics play a crucial role in assessing CKD progression and patient outcomes. Machine learning models, such as neural networks and random forests, are employed to predict the risk of disease progression based on a variety of clinical factors, including patient demographics, comorbidities, and previous treatment responses. These models can forecast the likelihood of reaching ESRD and the need for renal replacement therapy, guiding clinicians in making informed decisions about treatment adjustments [14]. By identifying high-risk patients early, healthcare providers can implement more aggressive therapeutic strategies or lifestyle modifications to slow disease progression.

AI also enhances patient adherence to treatment plans, which is critical in managing CKD. AI-driven tools provide personalized reminders, educational content, and real-time feedback to patients, promoting adherence to prescribed medications and lifestyle changes. These systems can identify patterns of non-adherence and predict potential challenges, enabling healthcare providers to intervene before these issues lead to significant complications. Improved adherence not only enhances patient outcomes but also reduces healthcare costs associated with disease progression and hospitalizations [13].

AI in transplant nephrology

The integration of AI into transplant nephrology is transforming the landscape of kidney transplantation, with significant implications for donor-recipient matching, predicting graft outcomes, and post-transplant monitoring.

AI technologies, particularly machine learning algorithms, are revolutionizing how donor-recipient matching is performed. Traditional matching methods, which heavily relied on human leukocyte antigen (HLA) compatibility and a limited set of clinical parameters, are now being enhanced by AI. Machine learning models can analyze vast datasets, including genomic data, electronic health records, and previous cross-matching outcomes, to identify patterns and optimize compatibility. These AI-driven systems can dynamically adjust their algorithms in real-time as new data becomes available, ensuring that the matching process remains current and tailored to individual patient needs [14, 15].

Once a transplant is performed, predicting graft survival and identifying potential rejection early is critical for patient outcomes. AI models excel in this area by processing complex variables, such as the donor's eGFR, kidney donor profile index (KDPI), recipient and donor body mass index (BMI), and immunological factors. These models can predict the likelihood of delayed graft function (DGF) and other complications, offering clinicians a powerful tool for risk stratification and personalized patient management [15, 16].

In post-transplant care, AI is increasingly used for continuous monitoring and management. AI-powered systems can integrate data from wearable devices and remote monitoring tools, providing real-time insights into the patient's health status. These systems can detect early signs of rejection or other complications, allowing for timely interventions. Moreover, AI's ability to personalize immunosuppressive therapy based on individual patient responses further enhances the long-term success of kidney transplants [16, 17].

AI in enhancing patient care and experience

AI is increasingly transforming patient care and experience, particularly in nephrology, where the use of AI-driven tools has led to significant improvements in patient engagement, remote monitoring, and overall care management. One of the most notable applications of AI in enhancing patient care is through AI-driven virtual assistants. These virtual assistants are designed to provide patients with real-time support and education about their conditions, treatment options, and medication management. By leveraging NLP algorithms, these tools can engage with patients in a conversational manner, offering personalized responses and ensuring that patients receive timely and accurate information [18].

AI-powered telehealth platforms are also playing a crucial role in managing kidney disease remotely. These platforms enable continuous remote monitoring of kidney function, allowing healthcare providers to track patients' health parameters in real time. This not only facilitates early detection of potential issues but also enables timely interventions, thereby reducing the risk of disease progression and hospital readmissions. The integration of AI in telehealth systems has proven particularly beneficial in managing CKD, where ongoing monitoring is critical for patient outcomes [19, 20].

Moreover, AI has enhanced patient-provider communication, a critical aspect of patient care that directly impacts patient satisfaction and adherence to treatment plans. AI-driven communication tools, such as chatbots and automated messaging systems, allow for seamless and continuous interaction between patients and healthcare providers. These tools can handle routine inquiries, schedule appointments, and provide medication reminders, thereby freeing up healthcare professionals to focus on more complex patient needs. Additionally, these systems can analyze patient data to identify potential health risks and recommend personalized interventions, further enhancing the quality of care provided [21].

Another significant application of AI in patient care is in the area of telemedicine, where AI-driven technologies facilitate virtual consultations and remote patient management. These technologies have become particularly important in the post-pandemic era, where the need for remote healthcare delivery has surged. AI-powered telemedicine platforms not only provide convenience for patients but also ensure that care is accessible to those in remote or underserved areas, thereby reducing health disparities [20, 22].

Ethical and regulatory considerations

The integration of AI in nephrology introduces significant ethical and regulatory challenges that must be addressed to ensure patient safety, data integrity, and equitable access to care. Ethical concerns primarily revolve around the potential biases embedded in AI algorithms, which may arise from non-representative training data. Such biases can lead to disparities in care, particularly affecting marginalized populations, thus exacerbating existing healthcare inequalities [23]. Moreover, the decision-making processes of AI systems, often termed "black box" models, lack transparency, making it difficult for healthcare providers and patients to understand or challenge AI-driven clinical recommendations [24].

Data privacy and security represent another crucial area of concern, especially given the sensitive nature of medical data used by AI systems. Ensuring compliance with regulations like the Health Insurance Portability and Accountability Act (HIPAA) is essential, but the global nature of AI technology complicates the alignment with varying international standards [25]. The use of large datasets to train AI models raises questions about consent and data ownership, as patients may be unaware of how their data is being utilized beyond their immediate care. Additionally, the potential for cyberattacks on AI systems necessitates robust cybersecurity measures to protect patient information and maintain trust in AI applications [26].

Regulatory frameworks for AI in healthcare are still evolving. Bodies such as the U.S. Food and Drug Administration (FDA) are developing guidelines for the approval and monitoring of AI-driven medical devices, emphasizing the need for continuous learning systems that can adapt to new data while maintaining safety and efficacy [23]. The International Organization for Standardization (ISO) and the Institute of Electrical and Electronics Engineers (IEEE) have also begun to establish standards for AI ethics and system design, which aim to guide the responsible development and implementation of AI technologies in healthcare [24].

The intersection of AI and nephrology thus requires a multi-faceted approach to regulation that encompasses ethical considerations, data protection, and international collaboration. Establishing clear guidelines will be essential to harness the benefits of AI while mitigating its risks, ensuring that advances in nephrology contribute to improved patient outcomes without compromising ethical standards or patient trust.

Challenges and limitations of AI in nephrology

AI has the potential to revolutionize patient care and experience in nephrology, offering new ways to enhance interactions and improve outcomes. One significant development is the use of AI-driven virtual assistants, which have been increasingly adopted in healthcare to provide patient education and support. These virtual assistants can answer questions, provide reminders about medication and appointments, and deliver personalized educational content, all of which empower patients to better manage their conditions. Such tools are especially valuable in nephrology, where patients often need to navigate complex treatment regimens [27].

Telehealth, augmented by AI, has further transformed kidney disease management by enabling remote monitoring and consultations. AI algorithms can analyze data from wearable devices or home monitoring systems, allowing healthcare providers to track vital signs and kidney function in real-time. This approach not only reduces the need for frequent hospital visits but also enables timely interventions, which can prevent complications and improve long-term outcomes for patients with CKD [27].

Another critical area where AI enhances patient care is through improved communication between patients and providers. AI-powered tools, such as chatbots or patient portals integrated with AI, facilitate more efficient communication, ensuring that patients receive timely responses to their concerns and that their data is seamlessly shared with healthcare providers. This enhanced communication is crucial in nephrology, where close monitoring and swift adjustments to treatment plans can significantly impact patient health [28].

Future directions and innovations

The future of nephrology is poised to be significantly shaped by emerging AI technologies. These advancements are expected to not only enhance current practices but also pave the way for entirely new approaches to kidney care. One of the most promising areas of innovation lies in the development of AI-driven predictive models. These models can analyze vast datasets from EHRs, genomics, and wearable devices to predict disease onset, progression, and response to treatment with remarkable accuracy [28]. Such capabilities are crucial in a field like nephrology, where early intervention can greatly improve patient outcomes.

Moreover, AI is expected to play a crucial role in advancing personalized medicine within nephrology. By integrating genetic, environmental, and lifestyle data, AI can help tailor treatment plans to the unique needs of each patient, potentially improving the efficacy of interventions and reducing adverse effects [23]. For example, AI can optimize drug dosing by considering a patient's specific metabolic profile, which is particularly important in managing conditions like CKD, where medication management is complex and critical.

The potential impact of AI on the future of kidney care extends beyond individual patient management to broader healthcare systems. AI technologies are likely to contribute to more efficient resource allocation, reducing healthcare costs while improving care quality. For instance, AI could streamline dialysis scheduling, predict patient no-shows, and optimize the use of dialysis centers, thus enhancing both patient care and operational efficiency [27].

Collaborative efforts between AI developers and nephrologists will be essential in realizing these future innovations. The development of AI tools tailored to nephrology requires a deep understanding of the clinical nuances of kidney diseases, which can only be provided by nephrology experts. Conversely, nephrologists need to be educated about AI technologies to effectively integrate them into clinical practice. This collaboration will ensure that AI applications are not only technically robust but also clinically relevant and ethically sound [28].

Conclusions

In conclusion, the integration of AI into nephrology is transforming the field by enhancing early diagnosis, personalizing treatment, improving patient monitoring, and revolutionizing renal replacement therapies. Despite the significant benefits, challenges such as technical limitations, ethical concerns, and the need for robust regulatory frameworks persist. However, with ongoing innovations and collaborative efforts between AI developers and nephrologists, AI has the potential to greatly improve patient outcomes and the overall quality of kidney care. The future of nephrology will likely see AI as an indispensable tool, driving precision medicine and optimizing patient care at every stage of kidney disease management.

References

1. *Briganti G, Le Moine O. Artificial Intelligence in Medicine: Today and Tomorrow. Front Med (Lausanne). 2020 Feb 5;7:27. doi: 10.3389/fmed.2020.00027.*

2. *Bekbolatova M, Mayer J, Ong CW, Toma M. Transformative Potential of AI in Healthcare: Definitions, Applications, and Navigating the Ethical Landscape and Public Perspectives. Healthcare (Basel). 2024 Jan 5;12(2):125. doi: 10.3390/healthcare12020125.*

3. *Umme HS, Tasnim S, Chowdhury MSH, et al. Early Prediction of Chronic Kidney Disease Using Machine Learning Algorithms with Feature Selection Techniques. In: Mahmud M, Ben-Abdallah H, Kaiser MS, Ahmed MR, Zhong N, editors. Applied Intelligence and Informatics: Revised Selected Papers of the III International Conference AII 2023. 2023, October 29-31; Dubai, United Arab Emirates. Communications in Computer and Information Science Series. Vol 2065. Cham: Springer; 2023. 224-242 pp. doi: 10.1007/978-3-031-68639-9_14.*

4. *Chiu YL, Jhou MJ, Lee TS, Lu CJ, Chen MS. Health Data-Driven Machine Learning Algorithms Applied to Risk Indicators Assessment for Chronic Kidney Disease. Risk Manag Healthc Policy. 2021 Oct 27;14:4401-4412. doi: 10.2147/RMHP.S319405.*

5. *Deepa B, Murugappan M, Sumithra MG, Mahmud M, Al-Rakhami MS. Pattern descriptors orientation and map firefly algorithm based brain pathology classification using hybridized machine learning algorithm. IEEE Access. 2021;10:3848-3863. doi: 10.1109/access.2021.3100549.*

6. *Fabietti M, Mahmud M, Lotfi A. Machine Learning in Analysing Invasively Recorded Neuronal Signals: Available Open Access Data Sources. In: Mahmud M, Vassanelli S, Kaiser MS, Zhong N, editors. Brain Informatics: Proceeding of the XIII International Conference BI 2020. 2020, September 19; Padua, Italy. Lecture Notes in Computer Science Series. Vol 12241. Cham: Springer; 2020. 151-162 pp. doi: 10.1007/978-3-030-59277-6_14.*

7. *Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. Nat Med. 2019 Jan;25(1):44-56. doi: 10.1038/s41591-018-0300-7.*

8. *Shickel B, Tighe PJ, Bihorac A, Rashidi P. Deep EHR: A Survey of Recent Advances in Deep Learning Techniques for Electronic Health Record (EHR) Analysis. IEEE J Biomed Health Inform. 2018 Sep;22(5):1589-1604. doi: 10.1109/JBHI.2017.2767063.*

9. *Parekh AE, Shaikh OA, Simran, Manan S, Hasibuzzaman MA. Artificial intelligence (AI) in personalized medicine: AI-generated personalized therapy regimens based on genetic and medical history: short communication. Ann Med Surg (Lond). 2023 Sep 13;85(11):5831-5833. doi: 10.1097/MS9.0000000000001320.*

10. *Fayos De Arizón L, Viera ER, Pilco M, et al. Artificial intelligence: a new field of knowledge for nephrologists? Clin Kidney J. 2023 Jul 29;16(12):2314-2326. doi: 10.1093/ckj/sfad182.*

11. *Nakamoto H, Aoyagi R, Kusano T, Ryuzaki M. Peritoneal dialysis care by using artificial intelligence (AI) and information technology (IT) In Japan and expectations for the future. Ren Replace Ther. 2023;9:31. doi: 10.1186/s41100-023-00479-y.*

12. *Zamanzadeh D, Feng J, Petousis P, et al. Data-driven prediction of continuous renal replacement therapy survival. Nat Commun. 2024 Jun 27;15(1):5440. doi: 10.1038/s41467-024-49763-3.*

13. *AI in remote patient monitoring: the top 4 use cases in 2024. Available from: https://healthsnap.io/ai-in-remote-patient-monitoring-the-top-4-use-cases-in-2024/. Accessed: March 11, 2024.*

14. *Isaza-Ruget MA, Yomayusa N, González CA, et al. Predicting chronic kidney disease progression with artificial intelligence. BMC Nephrol. 2024 Apr 26;25(1):148. doi: 10.1186/s12882-024-03545-7.*

15. *Seyahi N, Ozcan SG. Artificial intelligence and kidney transplantation. World J Transplant. 2021 Jul 18;11(7):277-289. doi: 10.5500/wjt.v11.i7.277.*

16. *Ramalhete L, Almeida P, Ferreira R, Abade O, Teixeira C, Araújo R. Revolutionizing Kidney Transplantation: Connecting*

Machine Learning and Artificial Intelligence with Next-Generation Healthcare - From Algorithms to Allografts. BioMedInformatics. 2024;4(1):673-689. doi: 10.3390/biomedinformatics4010037.

17. Peloso A, Naesens M, Thaunat O. The Dawn of a New Era in Kidney Transplantation: Promises and Limitations of Artificial Intelligence for Precision Diagnostics. Transpl Int. 2023 Dec 14;36:12010. doi: 10.3389/ti.2023.12010.

18. Bokhari SFH. Artificial Intelligence and Robotics in Transplant Surgery: Advancements and Future Directions. Cureus. 2023 Aug 23;15(8):e43975. doi: 10.7759/cureus.43975.

19. Badrouchi S, Bacha MM, Ahmed A, Ben Abdallah T, Abderrahim E. Predicting long-term outcomes of kidney transplantation in the era of artificial intelligence. Sci Rep. 2023 Dec 2;13(1):21273. doi: 10.1038/s41598-023-48645-w.

20. Burrell DN. Dynamic Evaluation Approaches to Telehealth Technologies and Artificial Intelligence (AI) Telemedicine Applications in Healthcare and Biotechnology Organizations. Merits. 2023;3(4):700-721. doi: 10.3390/merits3040042.

21. Milne-Ives M, de Cock C, Lim E, et al. The Effectiveness of Artificial Intelligence Conversational Agents in Health Care: Systematic Review. J Med Internet Res. 2020 Oct 22;22(10):e20346. doi: 10.2196/20346.

22. Ayers JW, Poliak A, Dredze M, et al. Comparing Physician and Artificial Intelligence Chatbot Responses to Patient Questions Posted to a Public Social Media Forum. JAMA Intern Med. 2023 Jun 1;183(6):589-596. doi: 10.1001/jamainternmed.2023.1838.

23. Brady AP, Allen B, Chong J, et al. Developing, purchasing, implementing and monitoring AI tools in radiology: Practical considerations. A multi-society statement from the ACR, CAR, ESR, RANZCR & RSNA. J Med Imaging Radiat Oncol. 2024 Feb;68(1):7-26. doi: 10.1111/1754-9485.13612.

24. Spiekermann S. IEEE P7000 - The First Global Standard Process for Addressing Ethical Concerns in System Design. Proceedings. 2017;1(3):159. doi: 10.3390/IS4SI-2017-04084.

25. Gupta DS, Mazumdar N, Nag A, Singh JP. Secure data authentication and access control protocol for industrial healthcare system. J Ambient Intell Humaniz Comput. 2023;14(5):4853-4864. doi: 10.1007/s12652-022-04370-2.

26. Eichelberg M, Kleber K, Kämmerer M. Cybersecurity in PACS and Medical Imaging: an Overview. J Digit Imaging. 2020 Dec;33(6):1527-1542. doi: 10.1007/s10278-020-00393-3.

27. Savoia M, Tripepi G, Goethel-Paal B, et al. European Nephrologists' Attitudes toward the Application of Artificial Intelligence in Clinical Practice: A Comprehensive Survey. Blood Purif. 2024;53(2):80-87. doi: 10.1159/000534604.

28. Badrouchi S, Bacha MM, Hedri H, Ben Abdallah T, Abderrahim E. Toward generalizing the use of artificial intelligence in nephrology and kidney transplantation. J Nephrol. 2023 May;36(4):1087-1100. doi: 10.1007/s40620-022-01529-0.

Received 04.07.2024
Revised 15.08.2024
Accepted 26.08.2024

Information about author

Kirolos Eskandar, Diakonie Klinik Mosbach, Germany; e-mail: kiroloss.eskandar@gmail.com; https://orcid.org/0000-0003-0085-3284

Conflicts of interests. Author declares the absence of any conflicts of interests and own financial interest that might be construed to influence the results or interpretation of the manuscript.
Information about funding. Not applicable.

Kirolos Eskandar
Diakonie Klinik, Mosbach, Germany

Штучний інтелект у нефрології: революція в діагностиці, лікуванні та догляді за пацієнтами

Резюме. Штучний інтелект (ШІ) швидко змінює галузь нефрології, пропонуючи інноваційні рішення, які покращують діагностику, лікування й догляд за пацієнтами. У цьому огляді літератури досліджуються існуючі та потенційні варіанти застосування штучного інтелекту в різних сферах нефрології. Обговорюється прогрес у ранній діагностиці, персоналізованому плануванні лікування, замісній терапії нирок і трансплантаційній нефрології, що став можливим завдяки ШІ. Крім того, вивчається, як штучний інтелект покращує догляд за пацієнтами завдяки дистанційному моніторингу, телемедицині та віртуальним помічникам. Незважаючи на величезні перспективи ШІ, у цьому огляді також обговорюються етичні, нормативні й технічні проблеми, що супроводжують його інтеграцію в клінічну практику. Підкреслюючи перетворювальний потенціал ШІ в нефрології, ми акцентуємо увагу на необхідності подальших досліджень та співпраці для повної реалізації його переваг у покращенні результатів лікування нирок.

Ключові слова: штучний інтелект; нефрологія; хронічна хвороба нирок; машинне навчання; персоналізована медицина