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EDITORIAL

Nephrology meets AI—environmental perspective

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Sustainable Nephrology TASK FORCE

Nephrology is eager for new developments and innovations. However, its environmental burden is significant, stemming from resource-intensive treatments, high waste levels, and greenhouse gas emissions associated with both clinical practices and the healthcare supply chain. Artificial intelligence (AI) has the potential to revolutionize the social, economic, and environmental sustainability of nephrology.

From our perspective, the main areas in which AI, as an ally, can help reduce the environmental impact of nephrology are those outlined here.

CLEANING LOW-VALUE CARE AND WASTE

The healthcare sector's footprint is often overlooked, assuming that all activities are essential and that their emissions are acceptable.

According to Organization for Economic Cooperation and Development, 20% of global healthcare spending is unnecessary (procedures with little or no positive health outcome) [1]. Healthcare waste results from clinical inefficiencies, missed prevention opportunities, overuse, duplicated procedures, etc. Reducing such waste and low-value procedures can lower costs and the carbon footprint (CFP) without harming patients.

Low-value care patterns are challenging to change, but methodologies such as Six Sigma (minimizing variation) and lean processes (removing waste) could enhance kidney care efficiency. Some examples of how AI can assist in the application of these principles are as follows: AI-models can detect low-value interventions, notify physicians, and integrate Choosing Wisely initiatives; clinical decision support systems use evidence-based guidelines and patient data to alert physicians when tests or treatments are unnecessary, narrowing the gap between clinical practice and best evidence, and flagging redundant or overused procedures, avoiding repetition; and machine learning (ML) identifies patients unlikely to benefit from unnecessary diagnostics, streamlining clinical workflows. AI can also optimize transport routes and delivery schedules, monitor energy usage to reduce consumption peaks, and predict supply needs to minimize waste.

PREDICTIVE ANALYTICS AND RISK ASSESSMENT TO REDUCE DEMANDS

The most substantial environmental benefit comes from lowering the need for resource-intensive therapies, such as dialysis, via public health prevention or early kidney disease detection: the "demand-side solution." Prevention remains the most effective option socially, economically, and environmentally. Early treatment or prevention may use fewer resources than late resource-intensive treatments. In our opinion, we urgently need to shift from substitutive therapies to prevention.

However, the rising incidence and prevalence of chronic kidney disease (CKD) stage 5 reflects our failure to prevent it. We still struggle to determine which patients will develop CKD 5 during their lifetime and, consequently, who will benefit from early diagnosis and intervention.

AI algorithms can assist in guiding clinical decisions and optimizing resource allocation by better identifying patients at higher risk of CKD progression through the processes of clustering or "phenomapping" [2]. Models, such as neural networks, achieve better performance than standard approaches such as Cox regression, with accuracy exceeding 96.7% in predicting CKD progression [3]. Additionally, AI can improve kidney graft allocation outcomes in transplantation.

Predicting complications, such as inpatient acute kidney injury, allows for early intervention and prevention. ML algorithms analyze data to develop predictive models, improving patient

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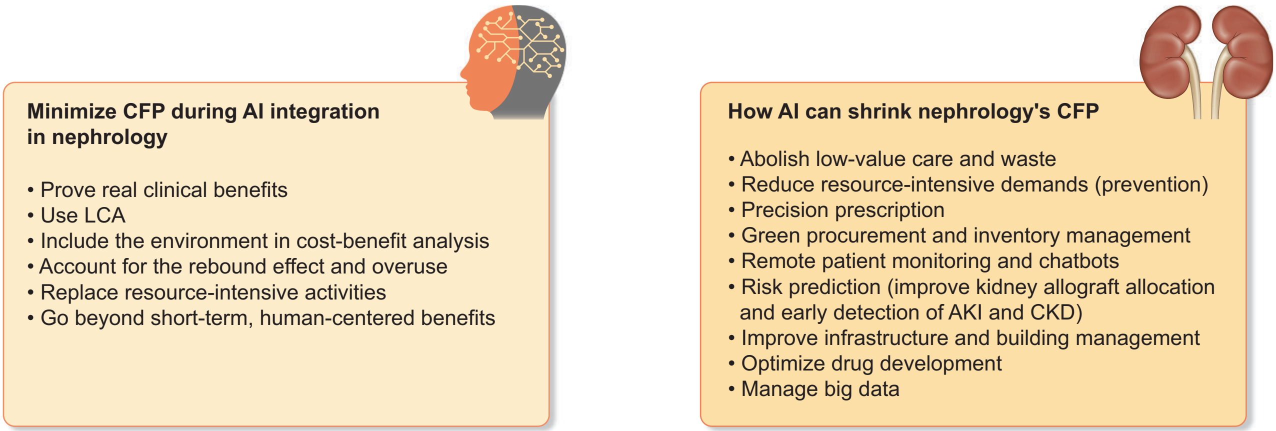

Figure 1: The balance between AI's carbon footprint and its potential benefits on the environmental sustainability of nephrology. AI, artificial intelligence; CFP, carbon footprint; LCA, life cycle assessment; AKI, acute kidney injury; CKD, chronic kidney disease.

outcomes and reducing economic and environmental costs. These models can also identify patients at risk of hospital readmissions.

PRECISION PRESCRIPTION IN NEPHROLOGY

In the 21st century, trial-and-error prescription are still in use. Our drug prescriptions rely on "average patient" and population data from guidelines and statistical tools, such as the number needed to treat, which assumes that only some patients will benefit from it. For patients with CKD, following disease-specific guidelines frequently leads to polypharmacy.

Combining trial-and-error prescriptions with an increasing number of drugs approved to delay CKD progression, creates a scenario of significant resource consumption and potential risk for patients.

AI analysis of large datasets can match individual characteristics with treatment outcomes, thereby enabling personalized drug regimens. This method enhances therapeutic effectiveness, minimizes adverse effects, increases patient satisfaction, and reduces the overall economic and environmental impact of medication. Technologies such as health digital twins (virtual models based on patient data and real-time updates) can help achieve these goals [4].

REMOTE PATIENTS MONITORING

Advancements in electronic information and communication technologies have made tele-medicine and remote monitoring essential for contemporary nephrology. AI can further reduce the CFP of these services by automating the routine inquiries that patients typically direct to physicians.

AI-driven chatbots alleviate the burden on providers, enabling them to concentrate on more complex cases that require specialized skills.

Self-monitoring technologies, including vital signs tracking, and soon, sensing devices, will enable CKD patients to self-test key parameters such as creatinine and urea (using tears or saliva), or hemoglobin (via conjunctival or nail images). These innovations support home therapies and reduce the need for travel and logistics, significantly lowering the footprint of outpatient clinics and laboratory operations [5].

GREEN PROCUREMENT

Of all healthcare emissions, 71% are primarily released from the healthcare supply chain (scope 3), which includes indirect emissions from activities not directly owned or controlled by the organization, such as production, transportation, waste treatment, pharmaceuticals, medical devices, and technologies, as defined by the Greenhouse Gas Protocol [6]. Healthcare practitioners and institutions can primarily influence scope 1 emissions (direct emissions from sources controlled by the organization, such as hospital operations) and scope 2 emissions (indirect emissions from purchased energy, by choosing renewable sources). However, larger institutions, such as national healthcare services or hospital groups, may have greater influence over scope 3 emissions due to their significant market power.

AI supports green procurement by identifying sustainable products and suppliers, promoting eco-friendly practices. It can also improve inventory management to minimize waste.

INFRASTRUCTURES AND BUILDINGS MANAGEMENT

In nephrology wards and hemodialysis units (including water treatment systems), AI can significantly reduce emissions through improved facility management, such as optimizing heating, air conditioning, water supply, lighting, and overall energy use. AI solutions can help these high-energy consuming facilities reduce their footprint and save energy by providing early feedback, personalized recommendations, and intelligent anomaly detection to optimize energy use and address abnormal consumption behaviors.

RESOURCE ALLOCATION TO ADDRESS CLIMATE CHANGES

Patients with CKD are particularly susceptible to the consequences of climate change. AI can help nephrology services adapt to climate change by predicting at-risk areas and populations during extreme weather events and efficiently directing resources to where they are most needed.

Resource allocation can be improved by predicting patient admission rates, identifying high-risk populations.

OPTIMIZATION OF DRUG DEVELOPMENT

Drug development has a 90% failure rate in phase I, and the overall rate is even higher when preclinical stages are included. AI can assist this complex process by analyzing large datasets to identify promising drug candidates, predict their efficacy and safety, and improve their design. AI can reduce costs by up to 50% and shorten timelines by over 12 months, with significant environmental benefits. Nephrology trials face specific challenges that can be supported by AI, such as elevated toxicity risks, drug interactions, dose adjustments, and prolonged follow-up.

DATA MANAGEMENT

Hospitals produce 50 petabytes of data annually, however, 97% of the data generated by the healthcare sector remains unused. By 2020, it was estimated that globally the healthcare sector would generate 2.3 million petabytes of data (equivalent to 2.3 trillion DVDs of data) [7]. Nephrology holds a large amount of unexplored data, the analysis of which could reveal fundamental information for understanding pathologies and therapeutic solutions. AI is essential for analyzing this information efficiently, enabling more effective resource allocation and reducing data waste and redundancy in healthcare.

Although the potential of AI in nephrology is immense, not everything that glitters is gold, and additional considerations must be made.

The development of AI algorithms requires extensive programming and training, which contributes to greenhouse gases emissions due to high computational power and electricity use. For instance, training a model such as ChatGPT generates emissions equivalent to 262 round-trip flights from Munich to New York.

The extraction of minerals, metals, and plastics for AI hardware has notable environmental consequences. Furthermore, the abstract concept of the "cloud" for remote data management contrasts with the real-world impact of mineral extraction and the energy used for data center cooling.

The World Economic Forum highlighted the potential of AI to accelerate environmental degradation, emphasizing the need for sustainable practices in AI development [8]. There are calls for more transparency, optimization of training, and focus on "green AI," which aims to achieve novel results without escalating computational costs and ideally reducing them.

Assessing AI's net environmental impact requires evaluating its entire lifecycle, from raw material extraction and manufacturing to usage and disposal (e.g. using the Life Cycle Assessment). Health justice and the One Health perspective should also assess AI's impacts on non-human species.

Addressing the "AI chasm," the gap between AI's theoretical potential and its clinical results, is crucial. AI in healthcare is often seen to enhance treatment quality, safety, and efficiency, however, its actual effectiveness is frequently unproven [9]. Only a few models have advanced to randomized controlled trials, and even fewer have shown meaningful clinical benefits.

Many current evaluation methods focus on demonstrating technology functionality rather than evidence-based outcomes. We agree that a proven accurate AI tool does not guarantee efficiency gains and emphasize the need to distinguish between AI's effectiveness (achieving more) and efficiency (accomplishing tasks with fewer resources) [10].

Evaluation of AI's footprint in nephrology requires consideration of the rebound effect in which increased efficiency may lead to higher demand. AI may be overused or used alongside other resource-intensive approaches instead of replacing them.

While incorporating environmental dimensions into nephrology innovations is crucial, it should not hinder progress. AI could be a valuable tool for achieving environmental sustainability goals in nephrology, however its potential benefits should be critically assessed and validated.

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CONFLICT OF INTEREST STATEMENT

None declared.

REFERENCES

1. ECD *Tackling Wasteful Spending on Health*, Paris: OECD Publishing. 2017. https://doi.org/10.1787/9789264266414-en (date last accessed 31 December 2024).
2. Tangri N, Ferguson TW. Artificial intelligence in the identification, management, and follow-up of CKD. *Kidney360* 2022;**3**:554–6. https://doi.org/10.34067/KID.0007572021
3. Zhu Y, Bi D, Saunders M *et al.* Prediction of chronic kidney disease progression using recurrent neural network and electronic health records. *Sci Rep* 2023;**13**:1–11. https://doi.org/10.1038/s41598-023-49271-2
4. Mariam Z, Niazi SK, Magoola M. Unlocking the future of drug development: generative AI, digital twins, and beyond. *BioMedInformatics* 2024;**4**:1441–56. https://doi.org/10.3390/biomedinformatics4020079
5. Sugawara Y, Hirakawa Y, Nangaku M. Telemedicine in nephrology: future perspective and solutions. *Clin Kidney J* 2024;**17**:ii1–8. https://doi.org/10.1093/ckj/sfae267
6. Das KP, Chandra J. A survey on artificial intelligence for reducing the climate footprint in healthcare. *Energy Nexus* 2023;**9**:100167. https://doi.org/10.1016/j.nexus.2022.100167
7. *How to Harness Health Data to Improve Patient Outcomes | World Economic Forum* Available from: https://www.weforum.org/agenda/2024/01/how-to-harness-health-data-to-improve-patient-outcomes-wef24/ (date last accessed 31 December 2024).
8. *AI Will Accelerate Sustainability—But is No Silver Bullet | World Economic Forum* Available from: https://www.weforum.org/stories/2024/09/ai-accelerator-sustainability-silver-bullet-sdim/ (date last accessed 31 December 2024).
9. Cresswell K, de Keizer N, Magrabi F *et al.* Evaluating artificial intelligence in clinical settings—let us not reinvent the wheel. *J Med Internet Res* 2024;**26**:e46407. 2024 Aug 7;26(1):e46407. https://doi.org/10.2196/46407
10. Jongsma KR, Sand M, Milota M. Why we should not mistake accuracy of medical AI for efficiency. *npj Digit Med* 2024;**7**:1. 2024 Mar 4;7(1):1–3. https://doi.org/10.1038/s41746-024-01047-2

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