

Minireview Article

ARTIFICIAL INTELLIGENCE IN NEPHROLOGY- ITS APPLICATIONS FROM BENCH TO BEDSIDE

Abstract

Artificial intelligence (AI) is a science of computer stimulated thinking processes and human behaviours, which involves computer science, psychology, philosophy and linguistics. Large patients' datasets can be accessed, acquired and easily stored for further processing. Computer aided diagnosis (CAD) is a technology which combines medical image and computer image processing to quantify and judge the characteristics of the focus accurately and timely. The function of CAD has been verified in many aspects, especially in skin cancer, breast cancer and lung cancer. AI can analyse the association of treatment protocols and efficacy from a large number of patients, develop models based on efficacy and risk factors, guide the choice of treatment protocols, and improve clinical efficacy. While AI medicine is still in its infant stage, In the future, AI will play a crucial role in clinics, alleviating the burden on clinicians and improving prompt diagnosis and management.

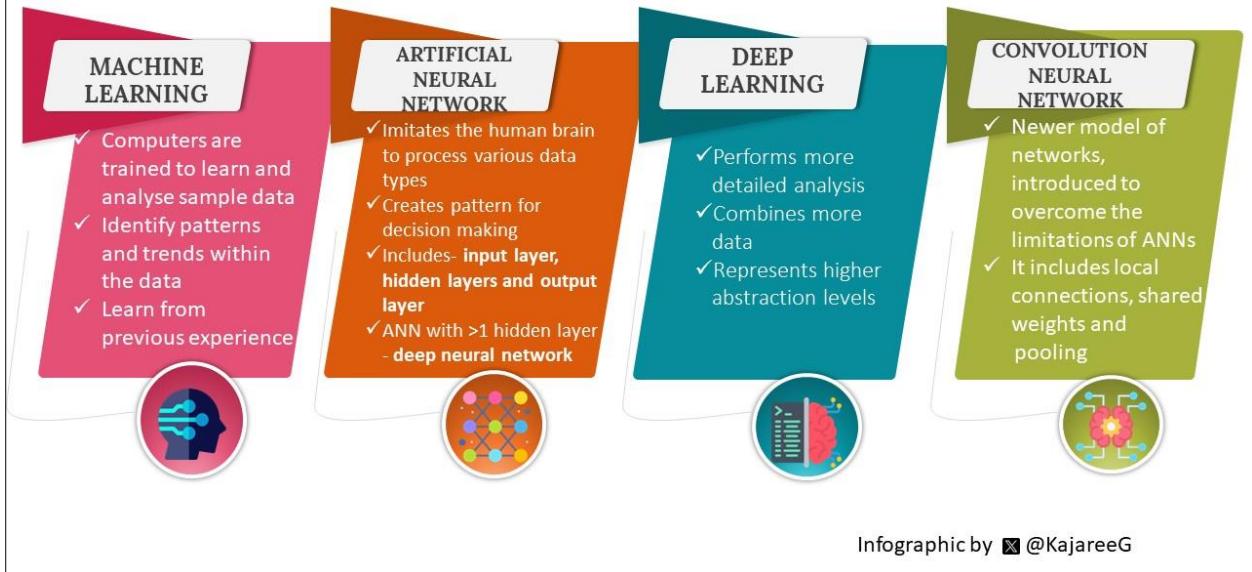
Keywords: Artificial intelligence, nephrology, treatment protocols, AI medicine

INTRODUCTION

Kidney disease is a major public health problem affecting 1 in 10 persons worldwide, most commonly caused by diabetes, hypertension, obesity and aging. According to the global burden of diseases, 800 million people worldwide suffer from kidney diseases and the incidence is increasing.¹ Artificial intelligence (AI) is a science of computer stimulated thinking processes and human behaviours, which involves computer science, psychology, philosophy and linguistics. Large patients' datasets can be accessed, acquired and easily stored for further processing. The key function of AI is to utilise databanks and extract valuable information.

Figure 1: Components of artificial intelligence

COMPONENTS OF ARTIFICIAL INTELLIGENCE



THE FUNCTION OF AI IN KIDNEY DISEASE


- A. **ALERTING SYSTEMS** – Early prediction of deterioration can play an important role in supporting health care professionals. An estimated 11% of hospital deaths occur subsequent to failure in prompt recognition and treatment of deteriorating patients.

ALERTING ACUTE KIDNEY INJURY (AKI) – AKI is a common critical illness in clinics, especially for elderly and perioperative patients. The incidence is 7-18% among hospitalised and 50% among ICU patients; it is increasing by 11% per year.² Approximately 2 million patients die due to AKI per year and the mortality rate is 10-30% for uncomplicated AKI patients and 30-80% in those with multiple organ failure.³ Early recognition and prevention of AKI is of utmost importance. Many scientists have tried to build models for early prediction of AKI which are summarised in table 1.

Table 1: Summary of the role of AI in predicting AKI

Study	Cohort size	Research type	AI algorithm	Conclusions	Limitations
Tomase et al ⁴	703782	Longitudinal data set	Recurrent neural network	Predicted 55.8% of all in patient episodes of AKI, and 90.2% of all AKI that required subsequent renal replacement therapy	Retrospective study



Yin et al ⁵	8800	Retrospective, single center study	Machine learning method – random forest	Good predictive ability of development of contrast induced nephropathy	Non case control study
Zimmerman et al ⁶	23950	Retrospective study	Multivariate logistic regression, random forest, ANN	Model can predict AKI onset in 66% patients 	Did not include comorbid diagnosis

ALERTING CHRONIC KIDNEY DISEASE (CKD) – Globally 844 million people are affected with chronic kidney diseases, and around 1 in 10 patients are affected with CKD in India. It not only increases morbidity and mortality; it poses a huge financial and administrative burden to the country. There should be prompt efforts to develop preventive and therapeutic measures to decrease the incidence and slow the progression of CKD.

A pilot program using e-technologies to detect CKD was conducted in Australia (Electronic Diagnosis and Management Assistance to Primary Care in Chronic Kidney Disease; EMAP-CKD). The software was built on algorithms trained to identify at-risk patients and to order a relevant screening test for CKD.⁷ In addition, several scientists have studied AI for alerting the early complications of CKD which have been summarised in table 2.




Table 2: Summary of the role of AI in alerting CKD

Study	Cohort size	Research type	AI algorithm	Conclusions	Limitations
Galloway CD et al ⁸	449380	Retrospective study	Deep neural network (DNN)	Detected hyperkalemia in 88% of CKD patients using two ECG leads	Retrospective study
Almansour NA et al ⁹	400	Retrospective study	Artificial neural network (ANN) Support vector machine (SVM)	Predicted CKD in early stages in 99.7% of patients. ANN performed better	Limited number of patients
Lin SY et al ¹⁰	48153	Retrospective	ANN, RF (radiofrequency)	Predicted one year outcome following dialysis in the aged and super-aged population accurately in 81%	No external validation
Kazemi et al ¹¹	936	Retrospective	ANN	Predicted early detection of type of kidney stone in nephrolithiasis	Retrospective study

B. COMPUTER AIDED DIAGNOSIS – DIAGNOSTIC ASSISTANCE

Computer aided diagnosis (CAD) is a technology which combines medical image and computer image processing to quantify and judge the characteristics of the focus accurately and timely. The function of CAD has been verified in many aspects, especially in skin cancer, breast cancer and lung cancer. The various applications have been summarised in Table 3.

Table 3: Role of CAD in nephrology

Type of diagnosis	Evidence	Number of patients	Benefits
A. Imaging diagnosis 	1. Kanishka et al ¹² used automated segmentation method 2. Timothy et al ¹³ used automated method 3. Automated deep feature classification (DFC) 4. Identification and classification of CAKUT	244 patients of ADPKD 2400 patients of ADPKD	Fast and reproducible diagnosis of TKV measurements Segmentation and computation of TKV Distinguish benign angiomyolipoma without visible fat and oncocytoma from malignant renal cell carcinoma
B. Pathological diagnosis 	1. Better classification of Banff scheme		Reduce intra and inter observer variability Reduces time
C. Make appropriate ICD codes 	1. Sina Rashidian et al used deep learning methods which is based on demographics, lab results, and medications	3	Predicted AKI and CKD in 91% and 94% respectively

C. GUIDING TREATMENT

Guidelines are formulated through large scale investigations and are the basis of decision making. Hence, these are population based and adjustments have to be made on individual basis. AI can analyse the association of treatment protocols and efficacy from a large number of patients, develop models based on efficacy and risk factors, guide the choice of treatment protocols, and improve clinical efficacy.

1. **ANEMIA TREATMENT** – Substantial progress has been made in the application of AI driven methods to provide ESA dosing information for patients with anemia due to CKD. In 2014, Carlo et al used Machine Learning (Multilayer Perceptron, MLP) and linear model to recommend suitable ESAs doses. The accuracy of MLP prediction model was more than 90% and it outperformed the previous approaches of hemoglobin prediction.¹⁴ In 2018, Maria et al also used a model which could help to improve anemia outcomes of patients with reduced



intake of ESA and less hemoglobin fluctuations.¹⁵ These studies are limited by small sample size and less follow up period.




2. **BLOOD PRESSURE AND FLUID VOLUME MANAGEMENT** – The prevalence of hypertension is 40-90% in patients with ESRD. Clinicians often reduce extracellular fluid volume overload to control BP which predisposes to intradialytic hypotension. Carlo et al developed a multiple end point model predicting session specific Kt/V, fluid volume removal, heart rate and BP in 2019 with relatively accurate precision.¹⁶
3. **WEARABLE DIALYSIS DEVICES** –Wearable dialysis devices can make the real-time analysis of equipment alarms, dialysis parameters, and patient-related data with a real-time feedback response. Martin et al combined AI and regenerative medicine technology to develop wearable dialysis devices.¹⁷ These devices can conduct continuous dialysis, remove toxins effectively and have little effect on hemodynamics. Another remarkable innovation is the implantable Renal Assist Device (iRAD) that uses micromachining techniques to fabricate a biohybrid system which mimics renal morphology and function.
4. **ASSISTANCE OF NEEDLE INSERTION** – An autonomous image guided robotic needle insertion for blood draws and intravenous insertions has also been designed that combined robotics, AI, computer vision and image technology.

D. **EVALUATING PROGNOSIS** –

AI can identify factors affecting prognosis by analysing database, and develop models evaluating the relationship between factors and prognosis.

Table 4: Role of AI in evaluating prognosis

Disease	Study	Number of patients	Variables	Benefits
1. Chronic kidney disease mineral bone metabolism (CKD-MBD)	A. Mariano et al ¹⁸	1758 HD patients	Calcium, phosphate, parathyroid hormone	Prediction of CKD-BMD 
	B. Kleiman et al ¹⁹		Calcium, phosphate, parathyroid hormone, kt/v	Prediction of calciphylaxis in CKD 
2. IgA nephropathy	Liu et al ²⁰	262 biopsy proven IgA cases	Oxford-MEST scores, C3 staining, eGFR	Prediction of ESRD status in IgA nephropathy

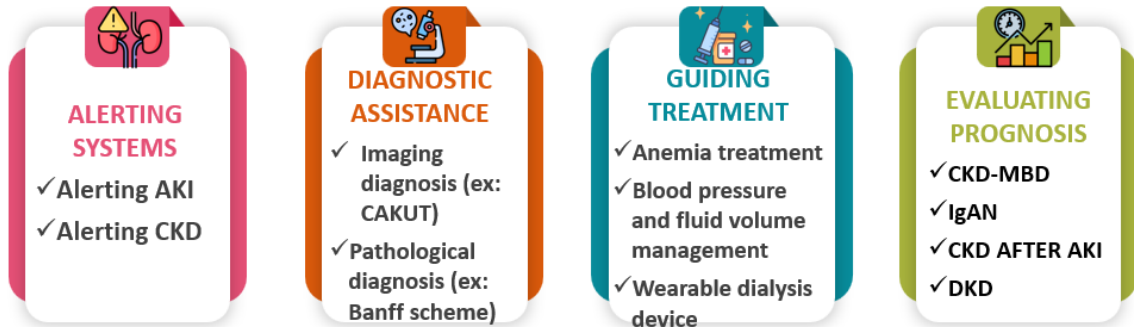
				
3.Diabetic kidney disease (DKD)	A. Leung RK et al (2013) ²¹	119 DKD patients and 554 without DKD type 2 DM patients	Age, age of diagnosis, lipid parameters, genetic polymorphisms	Prediction of DKD 
	B. Arianna et al (2018) ²²	1000 patients of T2DM	Age, gender, time from diagnosis, body mass index, glycated hemoglobin, hypertension, smoking	83% accuracy to predict DKD
4.Kidney transplantation	A. Lofaro et al ²³	80 patients of renal transplantation		Predicting outcomes of recipients and donors 
5.CKD after AKI	Several studies are underway			Predict the risk of CKD after AKI

Conclusion :

We are witnessing the development of medical practice from empirical medicine to evidence-based medicine to intelligent diagnosis and to AI-directed medicine. While AI medicine is still in its infant stage, In the future, AI will play a crucial role in clinics, alleviating the burden on clinicians and improving prompt diagnosis and management. At the same time, AI can support but never replace the human touch that ultimately heals a patient.

Figure 2: AI applications in nephrology

APPLICATION OF AI IN KIDNEY DISEASES



Infographic by @KajareeG

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