# Chronic Kidney Disease (CKD) At-Risk Patients' Detection Insights: A Survey

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***Abstract:***Chronic Kidney Disease (CKD) poses a significant global health challenge, necessitating early detection and intervention to mitigate progression and associated complications. This study explores the application of Deep Learning (DL) approaches for CKD detection. We review various deep learning architectures, including Convolutional Neural Networks (CNNs), Long Short-Term Memory (LSTM) networks, and ensemble methods, which have demonstrated promising results in analyzing medical datasets. By employing datasets that include clinical parameters, laboratory results, and patient demographics. Our investigations/study indicate that DL methods can significantly improve CKD detection rates compared to traditional techniques, paving the way for the development of robust, scalable decision-support systems in clinical practice. This research underscores the potential of Artificial Intelligence (AI) in transforming kidney health management and facilitating timely interventions for patients with CKD.

*Index Terms* **-CKD, Art-Risk Patients, DL, Disease, Risk Detection, Medical Datasets**

## I. INTRODUCTION

Chronic Kidney Disease (CKD) is a progressive condition characterized by a gradual decline in kidney function, affecting millions of individuals globally. According to the World Health Organization (WHO), CKD contributes significantly to global morbidity and mortality, often leading to End-Stage Renal Disease (ESRD) and necessitating costly interventions such as dialysis or kidney transplantation. Early detection and accurate diagnosis of CKD crucial for effective management and improving patient outcomes. In recent years, the advent of DL isa subset of AIhas revolutionized in different fields, including healthcare. Deep learning approaches, particularly neural networks, have shown remarkable capability in analysing complex and high-dimensional data. These methods can automatically extract relevant features from raw data, enabling them to outperform conventional techniques in various medical applications, including disease detection and classification. This study focuses on the recent literatures in the application of techniques for CKD detection, examining their potential to enhance diagnostic accuracy and facilitate early intervention. DL models can uncover intricate patterns that may elude traditional analytical methods. Further, this study will address the challenges associated with implementing DL in clinical settings, such as data scarcity, interpretability of models, and the integration of predictive analytics into existing healthcare workflows. This research aspires to provide a comprehensive survey to assist healthcare professionals in their understandings to the timely detection and management of CKD, thereby reducing the disease burden on individuals and healthcare systems. Similar machine learning-based prediction models have been explored in other domains as well. For example, Peerbasha [17] developed a predictive model for identifying academic performance patterns among students with bipolar disorder using ML and DL techniques. In a related work, Peerbasha [18] proposed classification-based predictive modeling for detecting at-risk bipolar disorder students. These studies demonstrate the broader applicability of machine learning for early detection of human-centered conditions, which parallels the objectives of CKD detection.

## II. MATERIALS & METHODS

**Datasets:**
Following are the reliable sources for datasets that can be utilized for CKD detection research using deep learning approaches:

- ***UCI Machine Learning Repository – CKD Dataset***
- ***Kaggle.com – CKD Dataset***
- ***OpenML – CKD Dataset***
- ***National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) –***
  - Data sets related to CKD and other kidney diseases
- ***Kidney Disease: Improving Global Outcomes (KDIGO***
  - *Various clinical studies and datasets*
  - *KDIGO focuses on improving global kidney disease management and provides access to datasets from clinical studies.*

*The adaptability of ML for pattern recognition across domains further strengthens its role in medical applications. For example, Raja et al. [20] employed machine learning for malicious URL detection by extracting structural patterns in web data. Although applied to cybersecurity, this work demonstrates how pattern recognition methodologies can be adapted to CKD data, where hidden correlations among clinical features must be identified.*

## III. RELATED WORKS

Alavi*et al.* explored [1] the efficacy of DL methods for predicting Chronic Kidney Disease (CKD) using a Convolutional Neural Network (CNN). They utilize the UCI CKD dataset, which includes a variety of clinical and laboratory parameters. Their implementation, conducted in TensorFlow, achieves an impressive accuracy of 94.5%. The study highlights the importance of feature extraction in improving predictive performance. The findings suggest that deep learning can significantly enhance CKD prediction, paving the way for early intervention strategies.

Kumar and Sharma proposed [2] a hybrid deep learning approach combining Long Short-Term Memory (LSTM) networks and Convolutional Neural Networks (CNN) for CKD prediction. They utilize a well-curated Chronic Kidney Disease dataset containing patient demographics, clinical parameters, and laboratory test results. The authors implement their model using Keras, achieving a remarkable accuracy of 96.3%. The hybrid model effectively captures temporal dependencies and spatial features, which significantly enhances prediction accuracy compared to standalone models. The study emphasizes the potential of hybrid architectures in clinical decision-making, suggesting that combining different deep learning techniques can yield better outcomes for CKD prediction.

Nguyen *et al.* presented [3] a comparative analysis of various deep neural network architectures for CKD prediction, focusing on the Feed forward Neural Network (FNN). They utilize the Kidney Disease Data Set, which comprises clinical features relevant to kidney health. The implementation is conducted using PyTorch, achieving an accuracy of 91.2%. The authors compare the FNN's performance against other deep learning models, including CNNs and LSTMs, to identify the most effective architecture for CKD prediction.
Singh *et al.* investigated the application [4] of ensemble DL techniques for predicting CKD, utilizing a stacked generalization approach. They developed a model to the Pima Indians Diabetes Database, which provides insights into diabetic patients' kidney health. The implementation, conducted with Scikit-learn, achieves an accuracy of 93.8%. Beyond kidney disease, machine learning has also shown significant impact in predicting other chronic health conditions. Peerbasha et al. [19] developed ML-based models to predict diabetes using classifiers such as decision trees, random forests, support vector machines, and logistic regression. Their study highlights how predictive modeling in healthcare can support early diagnosis and prevention strategies, which is highly relevant to CKD detection. The authors emphasize the advantages of ensemble methods in improving predictive performance by combining the strengths of various models. Their

study also includes an extensive feature importance analysis, enabling clinicians to focus on the most critical parameters affecting CKD, ultimately enhancing the utility of their predictive model in a clinical setting.

Wang and Liu proposed a DL approach [5] utilizing Auto encoder’s for CKD risk prediction, leveraging the MIMIC-III dataset, which encompasses a wide array of patient data in an intensive care context. The authors implement their model in TensorFlow, achieving an accuracy of 89.7%. They discuss the Auto encoder’s ability to learn efficient representations of the input data, facilitating better feature extraction for CKD prediction. Their findings highlight the model’s capability to identify at-risk patients, emphasizing its potential for timely intervention and management in healthcare settings. The study encourages further research into the use of unsupervised learning techniques in medical predictions.
Patel *et al.* explained the effectiveness [6] of transfer learning for CKD prediction using the InceptionV3 architecture. They leverage a pre-trained model on a Chronic Kidney Disease dataset, allowing them to utilize learned features from extensive datasets for improved prediction accuracy. The implementation in Keras, yields an accuracy of 95.0%. The authors emphasize the merits of transfer learning, particularly in scenarios, where limited labelled data is available. Their results demonstrate that transfer learning can significantly enhance the predictive capability of deep learning models, making it a valuable approach for CKD risk assessment in clinical practice.

Zhang and Chen introduced [7] a DL framework utilizing Recurrent Neural Networks (RNN) for the early detection of CKD. Their study uses a Chronic Kidney Disease dataset that includes longitudinal patient data. Implemented using Tensor Flow, the model achieves an accuracy of 92.5%. The authors highlight the advantages of RNNs in capturing temporal dependencies in patient health records, which is critical for early disease detection. Their findings suggest that incorporating temporal data can lead to more accurate predictions, reinforcing the importance of monitoring changes in patient health over time for CKD assessment.

Roy *et al.* investigated the impact [8] of feature selection techniques on CKD prediction using Convolutional Neural Networks (CNN). They employ the UCI CKD dataset and integrate Recursive Feature Elimination (RFE) to enhance model performance by selecting the most relevant features. Implemented in Keras, their model achieves an accuracy of 94.0%. The authors discuss how effective feature selection can lead to reduceover fitting and improved model interpretability. The study emphasizes the importance of feature relevance in machine learning applications, particularly in healthcare, where specific clinical parameters can significantly influence outcomes.

Lee *et al.* focused [9] on ensemble learning techniques for assessing CKD risk, utilizing both Random Forest and Gradient Boosting algorithms. They apply their methods to the Kidney Disease Data Set, achieving an impressive accuracy of 95.5%. The authors highlight the strengths of ensemble approaches in capturing complex patterns in the data, thereby improving predictive accuracy. They perform a comprehensive analysis of feature importance, helping healthcare professionals identify critical indicators for CKD. This study reinforces the idea that ensemble models can be highly effective in clinical settings, providing robust tools for early disease detection and risk stratification.

Torres *et al.* introduced [10]a deep learning techniques for CKD detection, focusing on the Squeeze Net architecture for its efficiency and accuracy. Using the Chronic Kidney Disease dataset, they implement their model in PyTorch, achieving an accuracy of 90.1%. The authors discuss Squeeze Net’s lightweight nature, making it suitable for deployment in resource-constrained environments, such as rural healthcare settings. They also explore various hyper parameter tuning strategies to optimize model performance. The findings suggest that innovative deep learning architectures like Squeeze Net can significantly contribute to timely CKD diagnosis, highlighting their relevance in modern healthcare
This paper provides [11] a broad overview of Machine Learning (ML) applications in diagnosing kidney disease, focusing on early-stage detection and classification of CKD stages. Various ML techniques like Support Vector Machine (SVM), Random Forest (RF), and Artificial Neural Networks (ANN) are evaluated. Ensemble methods and hybrid models show improved performance, especially in CKD classification. The paper emphasizes the importance of ML in detecting kidney disease early, improving outcomes, and reducing

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disease progression. Key performance metrics such as accuracy, sensitivity, and AUC are employed to compare models' effectiveness.

Machine learning models were developed to predict [12] the time to renal replacement therapy (RRT) for CKD patients based on clinical and laboratory data. This study develops a machine learning models to predict the time until RRT in CKD patients. Algorithms like LASSO regression, Random Forest, and Gradient Boosting Decision Trees (GBDT) were applied to clinical data. The results demonstrate that machine learning provides a more accurate prediction of CKD progression, surpassing conventional methods.

This paper developed [13] a DNN-based model to predict CKD using a publicly available dataset from the UCI repository. Data pre-processing steps including the handling missing values and outliers, and the model was trained on 25 attributes from 400 patient records.The DNN model achieved an accuracy of 98.8% for binary classification of CKD Vs. Non-CKD, outperforming the Random Forest classifier.This research introduces a Deep Neural Network (DNN) model to predict CKD using a dataset of 400 patients. The DNN outperformed Random Forest, achieving 98.8% accuracy in distinguishing CKD from non-CKD.

AfiaFarjana*et al.*, proposed [14] and compared nine ML algorithms to predict CKD. The algorithms included K-nearest neighbour's, SVM, Logistic Regression, Naïve Bayes, and advanced methods like XGBoost and LightGBM. Utilizing a CKD dataset with 14 attributes and 400 records, the authors concluded that the best-performing classifier reached around 99% accuracy. Python and Scikit-learn were used for implementation. Andrea Simeri*et al.*, explored [15] AI's role in predicting renal and cardiovascular risks in CKD patients. They emphasized the potential of AI, especially deep learning, to enhance risk prediction through comprehensive data integration. Although no specific dataset was used, AI models demonstrated high precision but faced challenges in data quality.Hira Khalid *et al.*, developed [16] a hybrid model for CKD prediction. Their hybrid approach combined Gradient Boosting, Naïve Bayes, Decision Trees, and Random Forests on the UCI CKD dataset. The hybrid model achieved a perfect 100% accuracy.

## IV. Comparative Analysis

**Research Domain Area: CKD in DL Applications**

**Table 1: A Detailed Description on CKD**

| Sl. No. | Year | Author (s) | Title of the Article | Method / Technique | Algorithm Used | Dataset Used | Tool | JournalName |
|---|---|---|---|---|---|---|---|---|
| 1 | 2022 | Alavi*et al.* | Predicting Chronic Kidney Disease Using DL | Deep Learning | Convolutional Neural Networks (CNN) | UCI CKD Dataset | Tensor-Flow | Journal of Medical Systems |
| 2 | 2023 | Kumar and Sharma | CKD Prediction Using Hybrid Deep Learning Approaches | Hybrid Deep Learning | LSTM and CNN | Chronic Kidney Disease Dataset | Keras | Applied Sciences |
| 3 | 2023 | Nguyen *et al.* | Deep Neural Networks for CKD Prediction | Deep Neural Networks | Feedforward Neural Network | Kidney Disease Data Set | PyTorch | Journal of Healthcare Engineering |
| 4 | 2023 | Singh *et al.* | Predicting CKD with Ensemble | Ensemble Learning | Stacked Generalization | Pima Indians Diabetes | Scikit-learn | IEEE Access |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Deep Learning Techniques | | | Database | | |
| 5 | 2022 | Wang and Liu | A DL Approach to CKD Risk Prediction | Deep Learning | Autoencoder | Medical Information Mart for Intensive Care (MIMIC-III) | Tensor-Flow | Journal of Clinical Medicine |
| 6 | 2023 | Patel *et al.* | Transfer Learning for CKD Prediction | Transfer Learning | InceptionV3 | Chronic Kidney Disease Dataset | Keras | Journal of Biomedical Informatics |
| 7 | 2023 | Zhang and Chen | A Deep Learning Framework for Early CKD Detection | Deep Learning | Recurrent Neural Networks (RNN) | Chronic Kidney Disease Dataset | Tensor-Flow | BMC Medical Informatics and Decision Making |
| 8 | 2023 | Roy *et al.* | CKD Prediction Using CNN and Feature Selection Techniques | Convolutional Neural Networks with Feature Selection | CNN with Recursive Feature Elimination | UCI CKD Dataset | Keras | Journal of Biomedical Science and Engineering |
| 9 | 2024 | Lee *et al.* | Ensemble Learning Techniques for CKD Risk Assessment | Ensemble Learning | Random Forest and Gradient Boosting | CKD Data Set | Scikit-learn | Expert Systems with Applications |
| 10 | 2023 | Torres *et al.* | Novel Deep Learning Techniques for CKD Detection | Deep Learning | SqueezeNet | CKD Dataset | PyTorch | Journal of Health Informatics |
| 11 | 2022 | Qezelbash, J., *et al.* | A survey of machine learning in kidney disease diagnosis | ML techniques | Support Vector Machine (SVM), Random Forest (RF), Artificial Neural Networks (ANN), Decision Trees (DT) | Nil | Nil | Machine Learning with Applications |
| 12 | 2024 | Okita, J., *et al.* | Development and validation of a ML model to predict time | Machine learning models | LASSO Regression, Random Forest, | Nil | Nil | BMC Nephrology |

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|---|---|---|---|---|---|---|---|---|
| | | | to renal replacement therapy in patients with chronic kidney disease | | Gradient Boosting Decision Trees (GBDT) | | | |
| 13 | 2022 | Jhumka, K., *et al.* | Chronic kidney disease prediction using DNN | DNN-based model to predict CKD | Deep Neural Network (DNN), Random Forest | UCI | Nil | IEEE Conference Proceedings |
| 14 | 2023 | Fatema, A. F., *et al.* | Predicting chronic kidney disease using machine learning algorithms | Comparative performance of nine ML algorithms | KNN, SVM, Logistic Regression, Naïve Bayes, Extra Trees, AdaBoost, XGBoost, LightGBM | Chronic Kidney Disease Dataset | Python, Scikit-learn | IEEE Conference Proceedings |
| 15 | 2024 | Simeri, A., *et al.* | AI in CKD: Methodology and potential applications | AI-based risk prediction integrating genetic, biomarker, and imaging data | Machine learning, Deep learning | Nil | AI/ML frameworks | Intl. Urology and Nephrology |
| 16 | 2023 | Khalid, H., *et al.* | Machine learning hybrid model for the prediction of CKD | Hybrid model combining multiple classifiers | Gradient Boosting, Naïve Bayes, Decision Tree, Random Forest | UCI CKD dataset | Python, SciPy, Scikit-learn | Computational Intelligence and Neuro science |

**V. RESULTS AND DISCUSSION**

In recent survey on CKD detection using DL approaches, different models have experimented with a significant improvement in predictive accuracy as compared to traditional methods. The analysis of aids in healthcare professionals in identifying critical biomarkers for CKD, facilitating better clinical decision-making.From the literatures, findings highlights the transformative potential of DL approaches for CKD detection.

## VI. CONCLUSION

The application of DL techniques for CKD detection represents a significant improvement in the field of medical diagnostics. This survey has highlighted the effectiveness of various DL models.

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