IJNRD.ORG ISSN : 2456-4184

INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG

An International Open Access, Peer-reviewed, Refereed Journal

Decentralized AI in Healthcare Precision CKD Diagnosis & Organ Donation Coordination

[1]Dr.Rohini Hanchate, [2]Nidhi Badve, Mrunal Pawar, [4]Pratiksha Tope

[1]Professor, [2]Student, [3]Student, [4]Student

[1]Computer Engineering Department,

[1]PCET'S Nutan Maharashtra Institute Of Engineering and Technology, Pune, Maharashtra, India.

Abstract: Chronic Kidney Disease (CKD) is a life-threatening condition requiring early diagnosis, while blood and organ donation face challenges like shortages and security concerns. This study integrates machine learning models—XGBoost, CatBoost, and LightGBM—with blockchain to enhance CKD prediction and donation systems. Using the UCI CKD dataset with feature selection techniques, XGBoost achieves 99.3% accuracy, outperforming traditional classifiers. Blockchain ensures secure patient records, while Ethereum Smart Contracts automate donor-recipient matching based on urgency. Machine learning predicts optimal matches and blood demand, with Linear Regression achieving an R-squared value of 0.998, reducing shortages and wastage. This AI-blockchain approach enhances CKD diagnostics and revolutionizes donation processes for a secure and efficient healthcare system.

Keywords: Chronic Kidney Disease, XGBoost, CatBoost, LightGBM, Blockchain, Organ Donation, Blood Donation, Ethereum Smart Contract, Machine Learning, Healthcare.

INTRODUCTION

Chronic Kidney Disease (CKD) is a silent and progressive condition that often remains undiagnosed in its early stages due to the absence of overt symptoms. As one of the leading causes of morbidity and mortality worldwide, early detection of CKD is crucial for preventing further progression to end-stage renal disease, where treatments like dialysis or organ transplantation become necessary. The growing prevalence of CKD has led to an increasing demand for accurate diagnostic tools that can identify the disease in its early stages, allowing for timely intervention and improved patient outcomes. While traditional diagnostic methods rely heavily on clinical assessments, recent advancements in machine learning (ML) have shown immense potential in enhancing the accuracy and efficiency of CKD prediction. Models such as XGBoost, CatBoost, and LightGBM, known for their superior predictive power, offer robust solutions for classifying and predicting CKD stages based on medical records and patient data.

In parallel, the healthcare sector faces critical challenges in the management of blood and organ donations, particularly in the context of shortages, mismatched donors, and the need for secure patient data handling. Blockchain technology has emerged as a promising solution to address these challenges by ensuring data security, transparency, and immutability. In addition to providing a secure framework for managing donor and recipient information, blockchain-based solutions offer smart contracts that automate the process of matching blood and organ donors to recipients based on medical criteria and urgency. When integrated with machine learning models, blockchain can further enhance the prediction and optimization of blood and organ donation processes, reducing wastage and improving efficiency in transplantations.

This research combines the strengths of XGBoost, CatBoost, and LightGBM in predicting CKD stages with the security and transparency offered by blockchain technology to propose an innovative approach for both disease prediction and blood/organ donation management. The proposed model not only aims to improve the early diagnosis of CKD through advanced ML algorithms but also seeks to optimize the donation process through a decentralized, secure, and automated system, ultimately contributing to more efficient healthcare delivery.

The primary objective of this research is to develop an AI-driven system for the early prediction of Chronic Kidney Disease (CKD) and an optimized organ donation management system. For CKD prediction, the goal is to create a machine learning-based model that accurately predicts CKD stages using patient medical data. This involves preprocessing and normalizing the data to improve efficiency, training and validating predictive models, and refining them to enhance accuracy. Additionally, the system aims to provide stage-specific treatment recommendations, assisting healthcare professionals in making informed decisions. Continuous learning and realtime monitoring mechanisms will be integrated to ensure adaptability and improved healthcare decision-making.

For the organ donation management system, the objective is to design an AI-powered organ matching and allocation framework. Blockchain technology will be employed to securely store donor and recipient data, ensuring transparency and integrity. The system will train and refine deep learning models to optimize organ matching accuracy and dynamically adjust compatibility criteria for better donor-recipient allocation. Furthermore, automated decisionmaking will be implemented for seamless organ distribution, supported by smart contracts for secure and efficient data transactions. The system will continuously monitor and adapt based on real-time patient data to improve efficiency and enhance healthcare outcomes. By leveraging AI, deep learning, and blockchain, this research aims to revolutionize CKD prediction and organ donation management, ultimately improving patient care and optimizing resource utilization.

Objective

This study aims to develop a decentralized AI-driven system that integrates federated learning and blockchain technology to enhance Chronic Kidney Disease (CKD) diagnosis and optimize organ donation coordination. By employing machine learning models such as XGBoost, CatBoost, and LightGBM, the system will predict CKD, determine its stages, and assess risk levels using patient data from multiple hospitals while ensuring data privacy through federated learning. Additionally, the research focuses on designing an efficient organ donor-recipient matching system based on clinical compatibility, geographical proximity, and urgency. Blockchain technology will be implemented to securely record and verify CKD predictions and organ donation transactions, ensuring transparency, security, and immutability. This approach aims to enhance diagnostic accuracy, improve organ allocation efficiency, and uphold strict data privacy and security standards.

Algorithm

- **Algorithm for CKD Prediction**

1. Start
2. Data Preprocessing
3. Train CKD Prediction Models
4. Make Predictions
5. Evaluate Model Performance
6. Deploy the Model
7. End

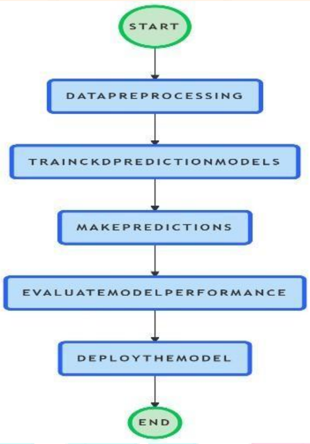

Fig 1. Flowchart of Algorithm for CKD Prediction

.

- **Algorithm for Organ Donation**

1. Start
2. Data Preprocessing
3. Create Smart Contract
4. Register Donor and Recipient Data
5. Match Donor to Recipient
6. Verification and Approval
7. Organ Donation Process
8. Log the Transaction
9. End

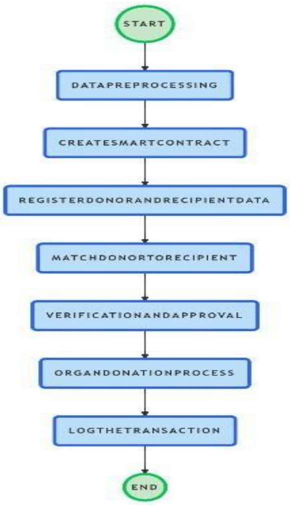

Fig 2. Flowchart of Algorithm for Organ Donation

Mathematical Model

CKD Diagnosis Prediction

- **Input Variables:** Let $X_i \in R^n$ represent the feature vector for patient i, encompassing clinical parameters such as age, blood pressure, serum creatinine levels, and other relevant biomarkers.

- **Binary Classification for CKD Diagnosis:** Define $\hat{Y}_{CKD,i} \in \{0,1\}$ as the binary label indicating CKD status, where 0 denotes 'No' and 1 denotes 'Yes'. The prediction function $f_{01}(X_i)$ outputs a probability $\hat{Y}_{CKD,i}$ that patient i has CKD:

$$\hat{Y}CKD,I = f01\ (Xi)\ldots\ldots.Eq.1$$

If $\hat{Y}_{CKD,i} \geq 0.5$, classify as 'Yes'; otherwise, classify as 'No' .

- MULTICLASS CLASSIFICATION FOR CKD STAGE: **IF $\hat{Y}_{CKD,I}$=1, PREDICT THE CKD STAGE** $\hat{Y}_{stage,i} \in \{1,2,3a,3b,4\}$ using the function $f_{stage}(X_i)$.

$$\hat{Y}stage,i = fstage(Xi)\ldots\ldots.Eq.2$$

The model outputs probabilities for each stage, and the stage with the highest probability is selected as the predicted stage.

- **Risk Percentage Calculation:** The risk percentages are derived from the predicted probabilities:

CKD Diagnosis Risk:

$$Risk_{CKD,i} = 100 \times \hat{p}_{CKD,i}$$

where $\hat{p}_{CKD,i}$ is the predicted probability that patient i has CKD.

CKD Stage Risk:

where $\hat{p}_{i,k}$ is the predicted probability that patient i is in stage k, and max k denotes the maximum probability across all stages.

Organ Donation Matching

System Integration

Integrate the CKD prediction model and the organ donation matching system into a unified platform. This platform utilizes federated learning to train models across multiple hospitals without sharing raw patient data, thereby preserving privacy. The blockchain component ensures that all data exchanges and transactions are secure, transparent, and immutable, fostering trust among stakeholders.

This mathematical model outlines the framework for a decentralized AI system that leverages advanced machine learning algorithms and blockchain technology to enhance CKD diagnosis and optimize organ donation matching, all while maintaining stringent data privacy standards.

Proposed Methodology

Proposed Methodology for CKD Prediction

1. Medical Data Submission: Patients' medical data, including test results and symptoms, is submitted into the system.
2. AI-Based Diagnosis: The system processes the submitted data using a machine learning model trained to detect CKD.
3. Local AI Model Training: Hospitals train AI models locally using patient data while maintaining privacy.
4. Federated Learning Integration: AI models from multiple hospitals share insights without transferring raw patient data, ensuring improved accuracy.
5. Model Prediction & Review: The trained AI model generates CKD predictions, which healthcare professionals review for validation.
6. Real-Time Decision Support: The system provides recommendations to assist doctors in diagnosing CKD and suggesting treatment plans.

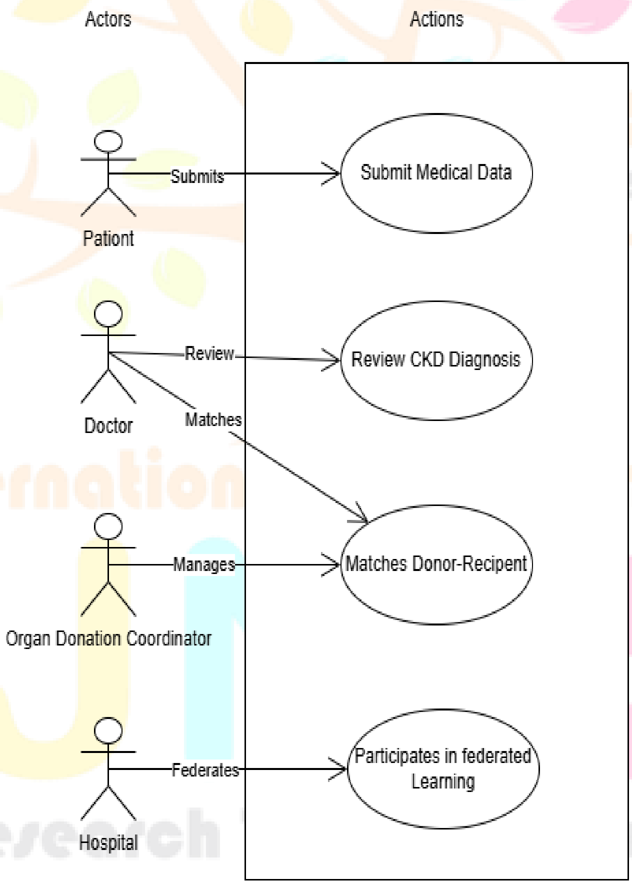

Fig 3. UML for CKD Prediction

Proposed Methodology for Organ Donation

1. Donor & Recipient Data Collection: Patients needing transplants and organ donors submit their medical profiles to the system.
2. AI-Based Donor-Recipient Matching: The system uses an AI model to analyze compatibility factors and match donors with suitable recipients.
3. Organ Matching System (Web Application): A secure web-based platform facilitates the donor-recipient matching process.
4. Blockchain Security for Transactions: Blockchain technology ensures secure, transparent, and tamper-proof donor-

recipient matching records.

5. Data Encryption & Privacy Protection: The system encrypts sensitive patient and donor information to maintain confidentiality.
6. Federated Learning for Model Enhancement: Multiple hospitals contribute to improving the AI-based donor-recipient matching model while preserving data privacy. 7. Real-Time Organ Allocation Support: The system provides real-time recommendations for organ allocation, improving efficiency in transplantation procedures.

Fig 4. UML for Organ Donation

The proposed system architecture for CKD prediction and organ donation integrates AI, federated learning, and blockchain to enhance healthcare efficiency, security, and accuracy. For CKD prediction, patients submit medical data, which is processed by an AI diagnostic model deployed at hospitals to predict CKD likelihood. Healthcare professionals review the diagnosis, and federated learning enables AI models from multiple hospitals to improve collaboratively without sharing raw patient data, ensuring privacy and compliance. For organ donation, donor-recipient profiles are analyzed by an AI model to determine the best matches based on medical compatibility, facilitated by a web-based organ matching system that securely handles data transactions via REST APIs. Blockchain technology records transplant transactions in a decentralized and tamper-proof ledger, ensuring transparency and security. The federated learning framework further enhances the matching accuracy by continuously updating AI models across hospitals. By leveraging AI for diagnosis, federated learning for privacy-preserving model updates, and blockchain for secure data management, this methodology provides a reliable and intelligent healthcare framework for CKD prediction and organ donation.

Implementation Model

a) Data Acquisition and Processing: The system gathers patient health data, including age, blood pressure, sugar levels, and albumin levels, through an interactive user interface. The collected data undergoes preprocessing to handle missing values, normalize input features, and ensure consistency before feeding into predictive models.

b) Chronic Kidney Disease (CKD) Prediction Model: Machine learning models such as XGBoost, CatBoost, and LightGBM are used to predict CKD stages and associated risk levels. The system processes the input data and provides a stage classification along with a risk percentage, helping in early diagnosis and treatment planning.

c) Graphical Representation of CKD Predictions: The predicted CKD stages and risk percentages from different models are represented graphically using line plots. These visualizations help in comparing model accuracy and understanding the trends in disease progression for better medical decision-making.

d) Organ Donation and Recipient Matching System: The organ donation module employs AI-based algorithms to match potential donors with recipients based on medical compatibility. The system considers factors such as blood group, tissue match, and urgency level to optimize the organ allocation process.

e) Blockchain for Secure Organ Donation Transactions: Blockchain technology ensures transparency, security, and integrity in the organ donation system. Every transaction, from donor registration to organ allocation, is securely recorded in a tamper-proof ledger, ensuring trust and preventing fraudulent activities.

f) Graphical Representation of Organ Matching and Blockchain Integration: The organ matching process is visualized through flow diagrams that highlight donorrecipient compatibility evaluation. Additionally, blockchain-based recordkeeping is represented graphically to showcase secure and transparent transaction management.

Result

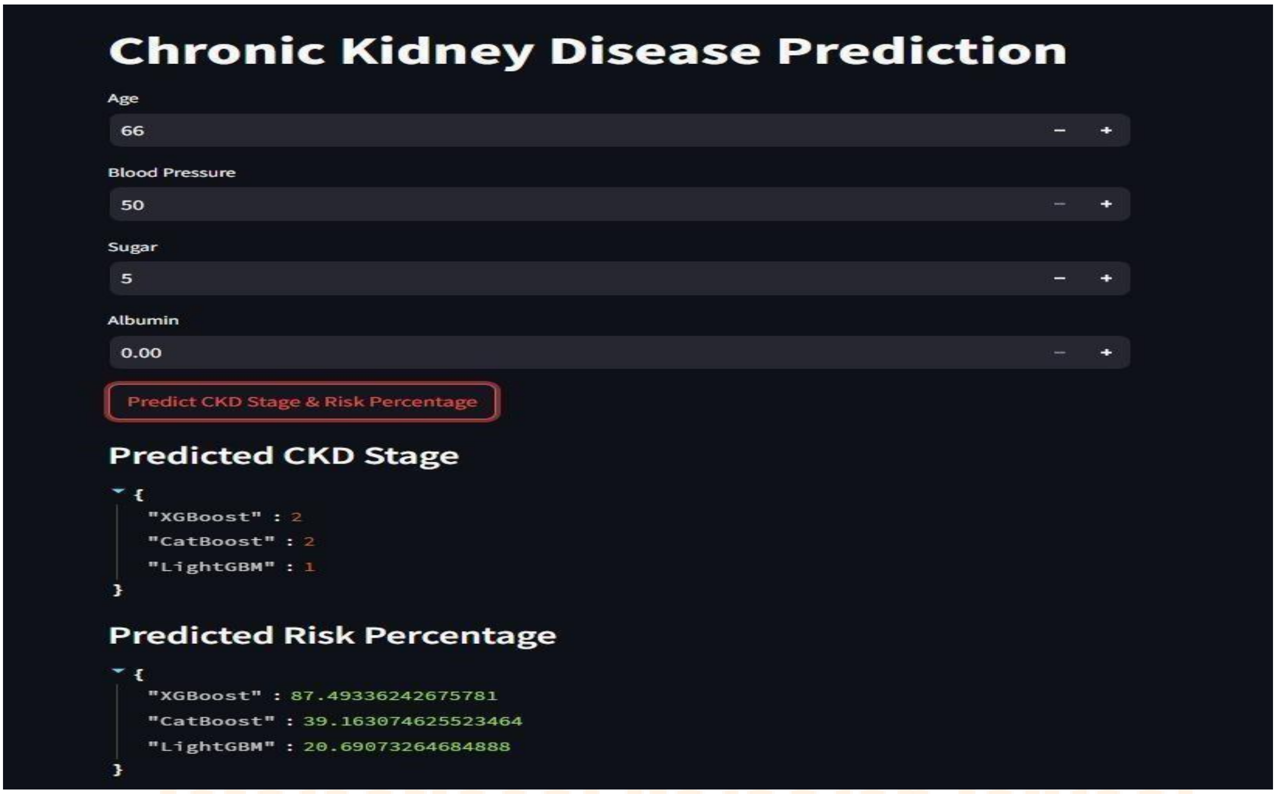

Fig 5. Information of CKD Prediction

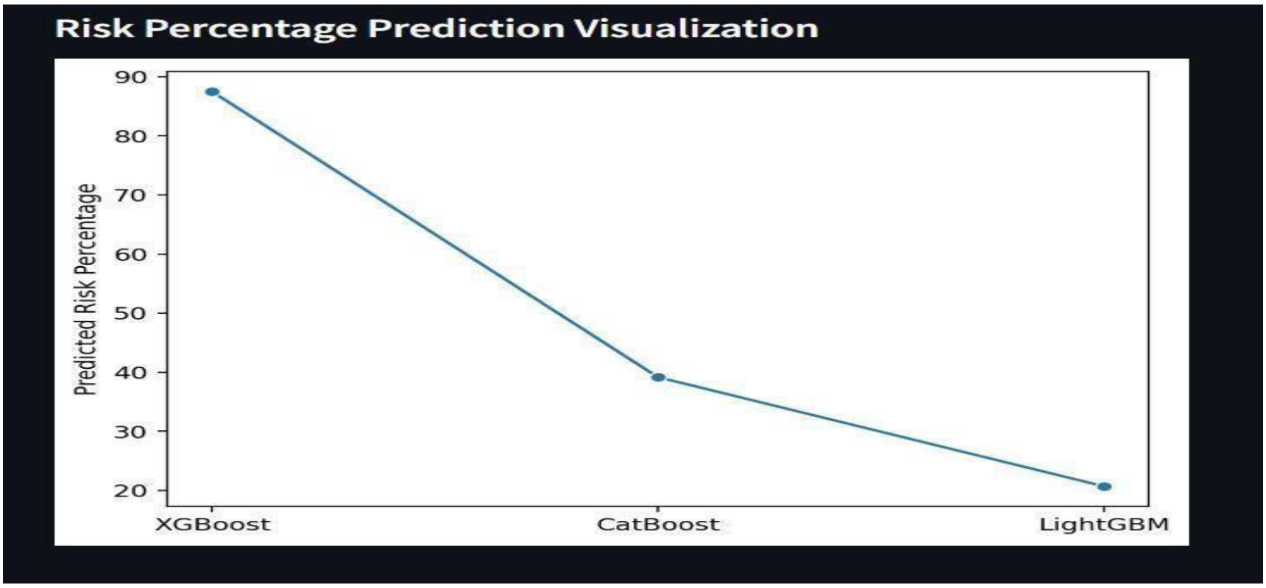

Fig 6. Risk Percentage

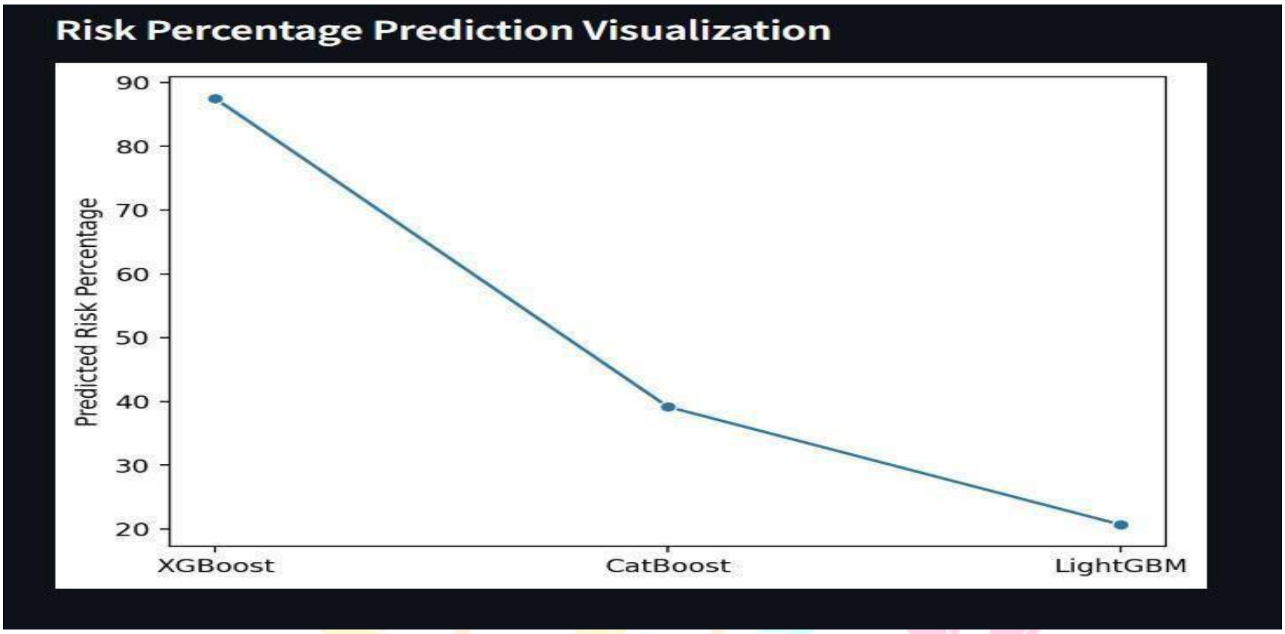

Fig 7. CKD Stage Prediction

Conclusion

The proposed research presents an AI-driven framework for chronic kidney disease (CKD) prediction and organ donation management, integrating advanced machine learning models, federated learning, and blockchain technology. The CKD prediction model utilizes XGBoost, CatBoost, and LightGBM for accurate classification of CKD stages and risk assessment, aiding in early detection and intervention. Federated learning ensures privacy-preserving model training by allowing multiple hospitals to contribute to AI improvements without sharing raw patient data. Additionally, blockchain technology is employed to secure donor-recipient transactions, ensuring transparency, security, and immutability in organ transplantation processes. This research contributes to enhancing clinical decision-making, improving patient outcomes, and optimizing organ allocation efficiency.

Application

The implementation of this system has significant implications in various healthcare domains. AI-based CKD diagnosis enables medical professionals to make data-driven decisions for early detection and timely treatment planning. Organ transplant management is optimized through AI-based donor-recipient matching, reducing waiting times and increasing transplant success rates. Blockchain-secured medical records provide a decentralized, tamper-proof solution for managing patient and donor data, ensuring compliance with privacy regulations. Remote patient monitoring allows individuals to track CKD risk levels, promoting proactive healthcare management. Additionally, collaborative AI model training using federated learning supports hospitals and research institutions in continuously improving disease prediction models while maintaining data confidentiality.

Future Scope

Future advancements in this research can enhance model accuracy and efficiency through deep learning techniques for more precise CKD stage classification and personalized treatment recommendations. The integration of IoT-enabled wearable devices can enable real-time monitoring of patient health indicators, providing dynamic risk assessments for CKD progression. A decentralized healthcare network using blockchain can facilitate seamless and secure medical data sharing across institutions, improving interoperability in healthcare systems. AI-driven organ viability assessment models can enhance donor organ selection, optimizing transplant outcomes. Additionally, the establishment of a global organ donation platform leveraging blockchain and AI can enable secure and ethical cross-border organ allocation, addressing global organ shortages.

This research establishes a secure, privacy-preserving, and intelligent healthcare system that enhances CKD prediction and organ donation management. By integrating AI, federated learning, and blockchain, the proposed framework ensures accuracy, transparency, and efficiency, ultimately advancing healthcare accessibility and patient care on a global scale.

References

[1] S. Y. Yashfi, N. Sakib, S. S. Pantho, M. A. Islam, T. Islam, Pritilata, and M. Shahbaaz, "Risk Prediction of Chronic Kidney Disease Using Machine Learning Algorithms," Dept. of Computer Science and Engineering, North Western University, Khulna, Bangladesh; Dept. of Electrical and Computer Engineering, Memorial University of Newfoundland, St. John's, Canada.

[2] A. Vijayalakshmi and V. Sumalatha, "Survey on Diagnosis of Chronic Kidney Disease Using Machine Learning Algorithms," Vels Institute of Science, Technology & Advanced Studies, Chennai, India.

[3] I. U. Ekanayake and D. Herath, "Chronic Kidney Disease Prediction Using Machine Learning Methods," Dept. of Computer Engineering, University of Peradeniya, Sri Lanka.

[4] R. S. Silva Jr., C. L. Pereira, N. A. C. Melo, G. C. S. Silva, C. M. Sousa Jr., N. P. S. Sousa, É. C. R. L. Caneiro, A. K. D. B. Filho, and E. E. C. Santana, "Chronic Kidney Disease Prediction using Machine Learning," Journal of Big Data.

[5] A. Y. Darveshwala, D. K. Singh, and Y. Farooqui, "Chronic Kidney Disease Stage Identification in HIV Infected Patients using Machine Learning," Parul University, Vadodara, India.

[6] P. Chittora, S. Chaurasia, P. Chakrabarti, G. Kumawat, T. Chakrabarti, Z. Leonowicz, M. Jasiński, R. Gono, Ł. Jasiński, and E. Jasińska, "Prediction of Chronic Kidney Disease – A Machine Learning Perspective," IEEE Transactions.

[7] S. Pal, "Chronic Kidney Disease Prediction Using Machine Learning Techniques," Springer Science+Business Media, 2022.

[8] D. A. Debal and T. M. Sitote, "Chronic Kidney Disease Prediction using Machine Learning Techniques," Journal of Big Data.

[9] M. A. Islam, M. Z. H. Majumder, and M. A. Hussein, "Chronic Kidney Disease Prediction Based on Machine Learning Algorithms," University of Dhaka, Bangladesh.

[10] C. Niyigena and S. Seol, "Survey on Organ Allocation Algorithms and Blockchain-based Systems for Organ Donation and Transplantation," School of Electrical, Electronics, and Communication Engineering, Korea University of Technology and Education, Korea.

[11] A. Lenskiy, "Blockchain-based Organ Donation Systems," College of Engineering and Computer Sciences, Australian National University, Canberra, Australia.

[12] L. A. Dajim, A. A. Al-Zuraib, S. A. Al-Farras, and R. M. Mathew, "Organ Donation Decentralized Application Using Blockchain Technology," King Khaled University, Saudi Arabia.

[13] B. S. Al-Shahrani, "Blockchain-Based Organ Donation Systems," King Khaled University, Saudi Arabia.

[14] P. L. Wijayathilaka, P. H. Pahala Gamage, K. H. B. De Silva, A. P. P. S. Athukorala, K. A. D. C. P. Kahandawaarachchi, and K. N. Pulasinghe, "Secured, Intelligent Blood and Organ Donation Management System - 'LifeShare'," Sri Lanka Institute of Information Technology (SLIIT), 2020 IEEE International ference on Advancements in Computing (ICAC).

International Research Journal
IJNRD
Research Through Innovation