

**AnemoCare**

# **AI Anemia Management for CKD Patients**

Graduation Project Summary

Faculty of Computers and Artificial Intelligence

Cairo University

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**Supervised by: Dr. Mustafa Shiple & Dr. Wael Wahby**

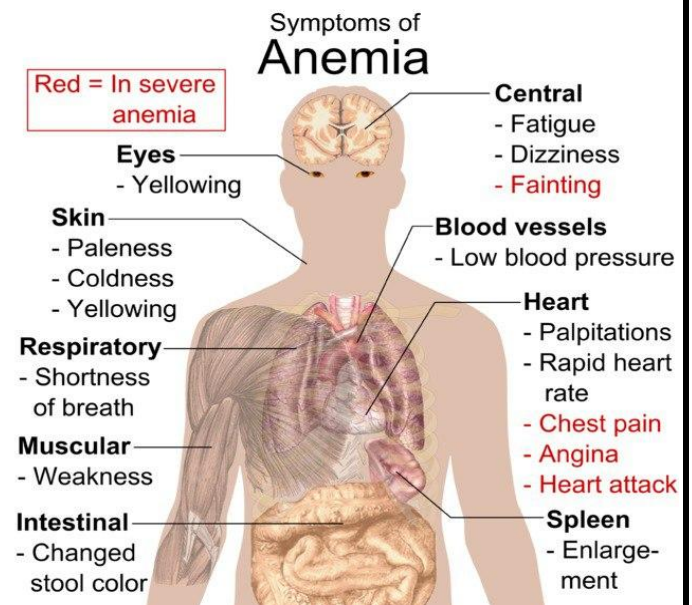
**Prepared by: Ahmed Mohammed Al-Ghazali**

## Abstract

This report presents the complete academic overview of AnemoCare, an AI-powered Clinical Decision Support System (CDSS) designed to optimize anemia management for patients with Chronic Kidney Disease (CKD). Anemia is a widespread complication in CKD due to the kidneys' reduced ability to produce erythropoietin. Conventional treatments involve complex dosing of Erythropoiesis-Stimulating Agents (ESAs), often based on manual analysis and subjective evaluation. AnemoCare introduces a data-driven approach integrating deep learning, probabilistic models, and explainable AI to predict hemoglobin (Hb) trends and recommend appropriate ESA doses. The system's workflow combines Optical Character Recognition (OCR) for data extraction, a Django-based backend for clinical integration, and a Flutter frontend for real-time decision support. This document expands on the technical, analytical, and experimental foundations of the system.

## 1. Introduction

Chronic Kidney Disease (CKD) is a progressive condition characterized by gradual loss of renal function, leading to multiple complications including anemia. Managing anemia effectively is crucial as it impacts patient quality of life, treatment costs, and overall survival. Traditional anemia management strategies rely on clinical experience and iterative dose adjustments, which can be inefficient and error-prone. Artificial Intelligence offers the potential to improve accuracy and efficiency in this process. The AnemoCare system applies AI to automate hemoglobin trend prediction and ESA dose optimization. Through machine learning and explainability tools such as SHAP, physicians can gain transparency into model reasoning while reducing workload and enhancing decision reliability.



## 2. RELATED WORK

Recent advancements in Artificial Intelligence (AI) and Machine Learning (ML) have significantly contributed to improving anemia management in patients with Chronic Kidney Disease (CKD). Several studies have focused on predicting hemoglobin (Hb) levels and optimizing Erythropoiesis-Stimulating Agent (ESA) dosages through data-driven methods. Table 3 summarizes key studies in this domain, outlining their datasets, applied AI techniques, and achieved performance outcomes.

Article	Dataset	AI Technique	Country	Hb Prediction / Results
Patient-Specific Modeling and Model Predictive Control Approach to Personalized Optimal Anemia Management	50 patients for 100 weeks	Model Predictive Control (MPC) with semi-blind robust model identification	USA (University of Louisville)	Focused on individualized ESA dose control; limited real-time deployment
AI for Clinical Decision Support in Anemia Management in Hemodialysis Patients (2016)	752 patients for 12 months	Artificial Neural Networks (ANNs)	Spain, Portugal, Czech Republic	Demonstrated effective Hb stabilization across 3 clinics
AI-Supported Anemia Control System (AISACS) (2021)	S1: 130 patients (46 weeks), S2: 81 patients (23 weeks), K1: 16 patients (6 weeks)	Neural Networks	Japan	Classification accuracy: 72–87%; Clinical appropriateness: 92–98%
Optimizing Anemia Management Using AI for Hemodialysis Patients (2024)	252 patients (12,993 samples)	Gated Recurrent Unit (GRU) with Attention Mechanism (GAM)	South Korea	$R^2 = 0.6$ , RMSE = 0.89, MAE = 0.65

## Discussion

From the comparative analysis of previous studies, it is evident that most existing AI-based systems concentrate on either predicting hemoglobin levels or optimizing ESA dosing using machine learning techniques such as Artificial Neural Networks (ANNs), recurrent neural architectures, or Model Predictive Control (MPC). Although these methods have achieved promising results in accuracy and clinical efficiency, they often lack real-world integration, interpretability, and adaptability across diverse patient populations.

For example, the MPC-based approach from the University of Louisville emphasized individualized control but did not include automated data integration or model transparency. Similarly, the European multicenter ANN study successfully stabilized Hb levels but was limited by its black-box nature and absence of uncertainty estimation. The AISACS project in Japan focused on prevention through neural networks but lacked a comprehensive explainable framework. More recent models, such as the GRU-Attention system developed in South Korea, improved predictive accuracy but still operated as stand-alone analytical models without clinical interface deployment.

### **Research Gap and Contribution of AnemoCare**

Despite the progress of prior research, none of the reviewed systems offered a complete clinical decision support solution that combines:

1. Personalized hemoglobin forecasting and ESA dose optimization within a unified platform.
2. Explainable AI (XAI) tools that provide transparency into the reasoning behind each recommendation.
3. OCR-based data extraction for automating the digitization of clinical records.
4. Role-based deployment (Doctor, Nurse, Patient, Administrator) for real-world usability and scalability.

To address these limitations, AnemoCare introduces an integrated AI-powered framework for anemia management in CKD patients. Its core innovations include:

- Utilizing regional clinical datasets from the Middle East to enhance model generalization and relevance.
- Incorporating deep learning and probabilistic models with uncertainty estimation for safer medical recommendations.
- Embedding explainable AI methods (e.g., SHAP) to increase physician trust and interpretability.
- Developing a modular mobile and web architecture (Flutter and Django) that bridges data-driven analytics with practical clinical workflows.

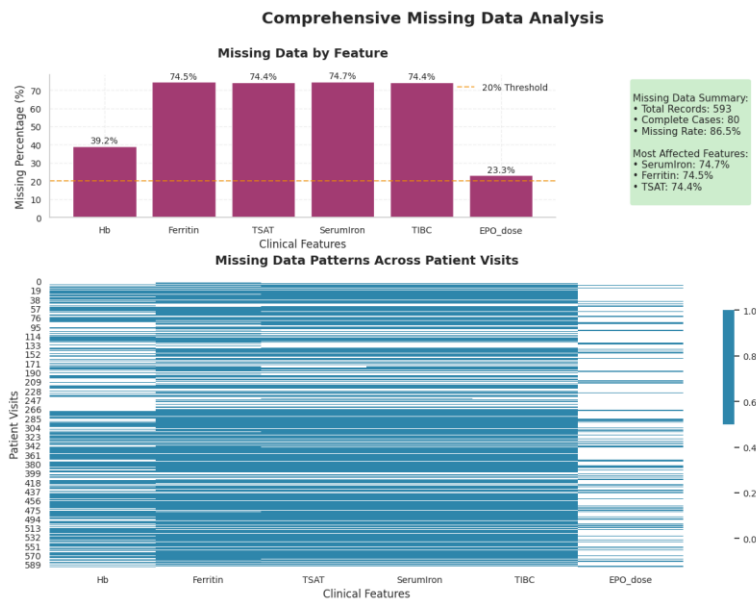
Through these contributions, AnemoCare advances beyond existing research by delivering a transparent, regionally adapted, and clinically deployable AI system for anemia management in CKD.

### 3. Objectives and Scope

The main objectives of the AnemoCare project are as follows:

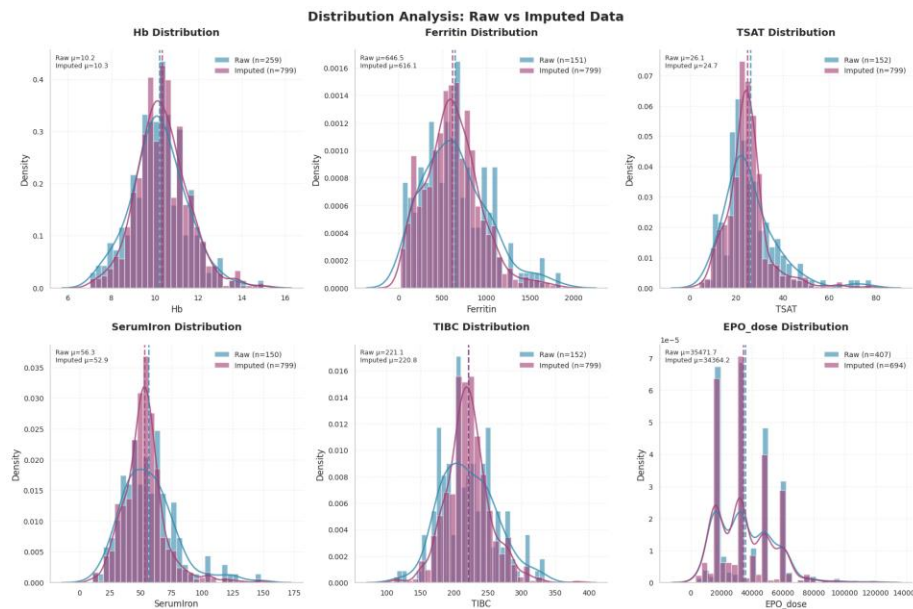
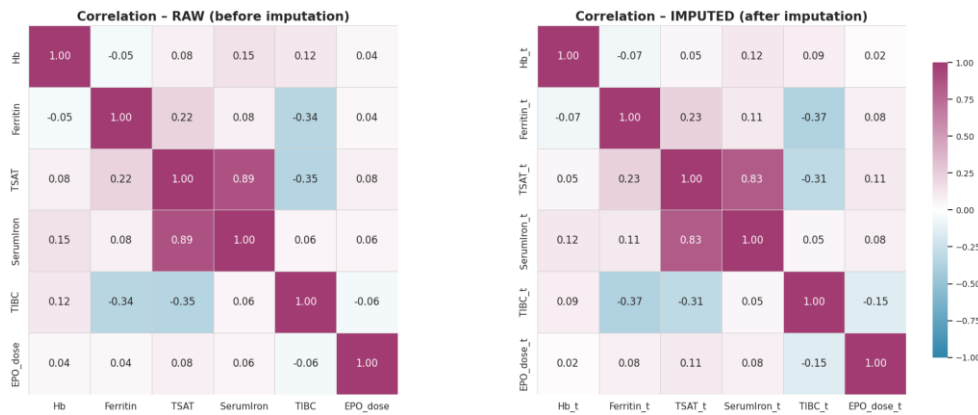
- Develop predictive models to estimate future hemoglobin levels.
- Optimize ESA dosing recommendations through regression and uncertainty modeling.
- Integrate OCR-based data extraction to reduce manual data entry.
- Provide role-based system access for healthcare professionals and patients.
- Ensure model interpretability through explainable AI methods.
- Deploy the system in a secure and modular architecture.

### 4. Dataset and Preprocessing



Data were collected from three hospitals, covering 79 CKD patients (~300 visits). The dataset included features such as Hemoglobin, Ferritin, TSAT, TIBC, and ESA doses. Due to extensive missing data, the Last Observation Carried Forward (LOCF) method was used for imputation after consultation with medical experts. Feature

engineering introduced temporal lag features, rolling averages, and clinical flags to improve model interpretability.



## 5. Proposed Models

Multiple models were explored for prediction and recommendation tasks:

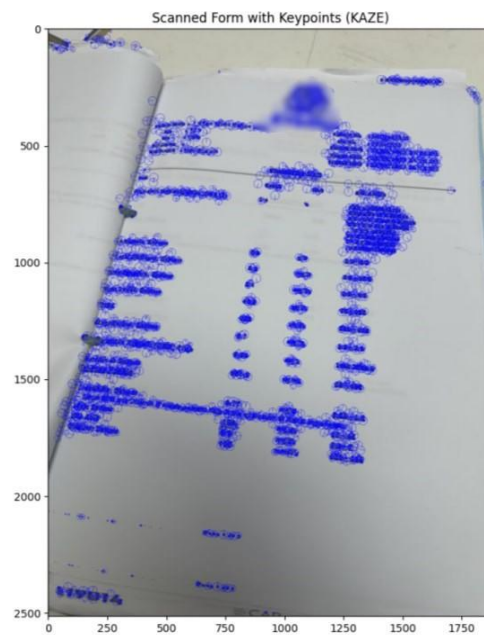
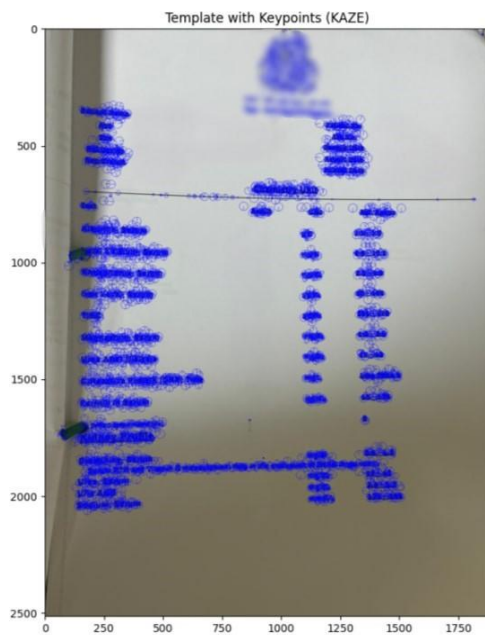
- **GRU (Gated Recurrent Unit):** Captures temporal relationships with fewer parameters.
- **LSTM (Long Short-Term Memory):** Handles long-range dependencies in patient data.
- **XGBoost:** Gradient boosting model used for regression and quantile estimation.
- **Gaussian Process Regression (GP):** Selected final model due to its uncertainty estimation and interpretability.

## 6. Experimental Results

The **Gaussian Process (GP)** and **XGBoost models** achieved the **best balance between accuracy and interpretability**. GP provided reliable uncertainty estimates, crucial for safe medical recommendations. Model performance metrics:

- **Mean Absolute Error (MAE): 0.65**
- **RMSE: 0.97**
- **R<sup>2</sup> Score: 0.58**

And for the OCR accuracy improved from 65% to 95% after KAZE-based preprocessing, ensuring accurate digitization of medical records.



Original image	65%
Using Global threshold	62%
Using Adaptive threshold	67%

Using Key-point based perspective	85%
Using Key-point based perspective and adaptive threshold	95%

## 7. System Design

The system combines a Django REST backend with a Flutter mobile frontend. The backend manages user authentication, data storage, and API communication, while the Flutter app enables user interaction. Doctors can upload lab images for OCR extraction or manually enter data. The AI engine predicts Hb and recommends ESA doses, which doctors can review before confirmation.

The complete mobile application source code is available on GitHub [here](#).

## 8. Conclusion and Future Work

AnemoCare demonstrates the potential of Artificial Intelligence to transform anemia management in patients with Chronic Kidney Disease (CKD). By combining deep learning, probabilistic modeling, and explainable AI, the system delivers accurate, transparent, and clinically interpretable predictions for hemoglobin levels and ESA dose recommendations. The integration of OCR and a modular mobile-web architecture further enhances usability and adaptability in real-world clinical environments.

The current version of AnemoCare has been developed and validated using data collected from a **single hospital in Egypt**, which provided valuable insights into the feasibility and accuracy of the proposed models. However, to ensure broader clinical applicability and improve model robustness, **future work will focus on retraining and validating the system using data aggregated from multiple hospitals across Egypt and other Middle Eastern countries**. This regional expansion will enhance the model's ability to generalize across diverse patient populations and healthcare settings.

In addition, future developments will involve **deploying AnemoCare in hospital networks for real-time clinical use**, integrating continuous patient data from wearable health sensors, and **incorporating reinforcement learning** for adaptive dosing recommendations. The introduction of **clinician dashboards with advanced visual explainability tools** will further improve transparency, trust, and clinical decision-making, positioning AnemoCare as a scalable and impactful AI solution for anemia management in CKD patients.

## References

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