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Machine learning approach to predict dialysis initiation in CKD stage 3-5 patients: a multi-center study

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Objectives : Optimal timing for initiating maintenance dialysis in stage 3-5 chronic kidney disease (CKD) patients is challenging. This study aimed to develop and validate a machine-learning (ML) model for early personalized prediction of maintenance dialysis initiation within 1-year and 3-year timeframes among stage 3-5 CKD patients.
Methods : Retrospective electronic health record data from the Taipei Medical University clinical research database were utilized. Newly diagnosed advanced CKD patients between 2008 and 2017 were identified. The observation period spanned from the diagnosis of CKD stage 3-5 until the maintenance dialysis initiation or a maximum follow-up of 3 years. Predictive models were developed using patient demographics, comorbidities, laboratory data, and medications. The dataset was divided into training and testing sets to ensure robust model performance. Model evaluation metrics, including area under the curve (AUC), sensitivity, specificity, positive predictive value, negative predictive value, and F1-score, were employed.
Results : A total of 6,123 and 5,279 patients were included for 1-year and 3-year of the model development. The artificial neural network (ANN) demonstrated better performance in predicting maintenance dialysis initiation within 1 year and 3 years, with AUC values of 0.96 and 0.92, respectively (Table 1). Important features such as baseline estimated glomerular filtration rate (eGFR) and albuminuria significantly contributed to the predictive model (Figure 1).
Conclusions : This study demonstrates the efficacy of a machine learning approach in developing a highly predictive model for estimating the timing of maintenance dialysis initiation in patients with advanced CKD. These findings have important implications for personalized treatment strategies, enabling improved clinical decision-making and potentially enhancing patient outcomes.

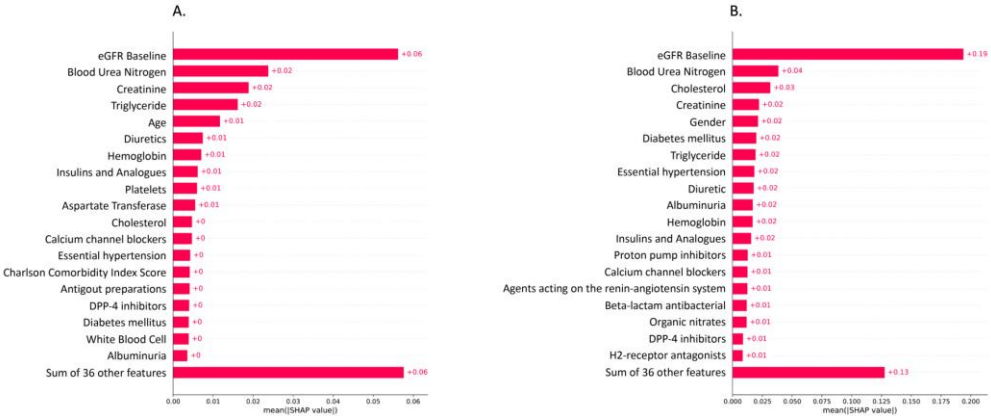
Table 1_Summary of different classification model.jpg

Table 1. Summary of different classification models

Classifiers	Training AUC	Testing AUC	Accuracy	Sensitivity	Specificity	Precision	F1-score
1-year prediction model performances							
Logistic Regression	0.92	0.90	0.80	0.89	0.79	0.39	0.71
Linear Discriminant Analysis	0.92	0.90	0.80	0.87	0.79	0.39	0.67
Gradient Boosting Classifier	0.98	0.89	0.81	0.83	0.81	0.40	0.63
LGBM Classifier	1.00	0.86	0.76	0.83	0.75	0.34	0.60
Ada Boost Classifier	0.97	0.81	0.83	0.69	0.85	0.41	0.51
Random Forest Classifier	1.00	0.89	0.82	0.85	0.82	0.42	0.65
XGB Classifier	1.00	0.87	0.82	0.80	0.82	0.41	0.63
ANN*	**0.99**	**0.96**	**0.89**	**0.88**	**0.75**	**0.39**	**0.60**
3-year prediction model performances							
Logistic Regression	0.91	0.90	0.80	0.88	0.77	0.61	0.82
Linear Discriminant Analysis	0.92	0.91	0.83	0.86	0.82	0.66	0.81
Gradient Boosting Classifier	0.96	0.91	0.82	0.84	0.81	0.65	0.81
LGBM Classifier	1.00	0.90	0.80	0.89	0.76	0.60	0.82
Ada Boost Classifier	0.95	0.89	0.79	0.84	0.78	0.60	0.80
Random Forest Classifier	1.00	0.90	0.80	0.88	0.77	0.61	0.82
XGB Classifier	1.00	0.90	0.82	0.83	0.82	0.65	0.80
ANN*	**0.95**	**0.92**	**0.82**	**0.87**	**0.79**	**0.63**	**0.73**

Note. AUC, Area Under the receiver operating characteristic Curve; LGBM Classifier, Light Gradient Boosting Machine Classifier; XGB Classifier, extreme Gradient Boosting Classifier; ANN, Artificial Neural Network; *, Best model based on AUC values

Table 1_Summary of different classification model.jpg


A.
eGFR Baseline +0.06
Blood Urea Nitrogen +0.02
Creatinine +0.02
Triglyceride +0.02
Age +0.01
Diuretics +0.01
Hemoglobin +0.01
Insulins and Analogues +0.01
Platelets +0.01
Aspartate Transferase +0.01
Cholesterol +0
Calcium channel blockers +0
Essential hypertension +0
Charlson Comorbidity Index Score +0
Antigout preparations +0
DPP-4 inhibitors +0
Diabetes mellitus +0
White Blood Cell +0
Albuminuria +0
Sum of 36 other features +0.06
0.00 0.01 0.02 0.03 0.04 0.05 0.06
mean(|SHAP value|)
B.
eGFR Baseline +0.19
Blood Urea Nitrogen +0.04
Cholesterol +0.03
Creatinine +0.02
Gender +0.02
Diabetes mellitus +0.02
Triglyceride +0.02
Essential hypertension +0.02
Diuretic +0.02
Albuminuria +0.02
Hemoglobin +0.02
Insulins and Analogues +0.02
Proton pump inhibitors +0.01
Calcium channel blockers +0.01
Agents acting on the renin-angiotensin system +0.01
Beta-lactam antibacterial +0.01
Organic nitrates +0.01
DPP-4 inhibitors +0.01
H2-receptor antagonists +0.01
Sum of 36 other features +0.13
0.000 0.025 0.050 0.075 0.100 0.125 0.150 0.175 0.200
mean(|SHAP value|)