THE KOREAN SOCIETY OF NEPHROLOGY
APCN & KSN 2024
June 13(Thu) - 16(Sun), 2024 Coex, Seoul, Korea
Promoting Sustainable Kidney Health: The Asia-Pacific and Beyond

Abstract Submission No.: A-0507

A noninvasive Diagnostic model for IgA nephropathy in Chinese population

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Objectives : Immunoglobulin A nephropathy (IgAN) is the most common primary glomerulonephritis worldwide. With the current development of treatment of IgAN, its diagnosis is of significance. Renal pathological biopsy is the gold standard for diagnosing IgAN. However, it is invasive and cannot be implemented in many patients due to contraindications. We aimed to construct a noninvasive evaluation model to predict the risk of IgAN using different machine learning approaches.
Methods : We retrospectively screened patients with IgAN and non-IgAN who has undergone kidney biopsy from January 2014 to January 2024 in two centers.The patients were seperated into an internal cohort and an external cohort.Clinical manifestations and laboratory test results were gathered.LR, RF, KNN,SVM,DT and XGBoost models were constructed. The models' predictive capabilities were assessed through ROC curves, sensitivity, specificity, accuracy and F1-scores.The Shapley additive explanations (SHAP) algorithm was employed to elucidate the contributions of the variables.
Results : In total, 1463 patients were assigned,including 504 patients with IgAN and 958 ones with non-IgAN. Patients with IgAN were randomly assigned into a training cohort (70%,n=368) to develop the model and a validation cohort (30%, n=137).There were no statistical differences in any clinical characteristics between the training and validation cohorts.Twenty variables were selected for model development. Six machine learning models were developed using these variables after evaluating their multicollinearity.In the validation cohort, the XGBoost model performed best, demonstrating the highest AUC (0.831), F1-Score(0.662), accuracy (0.761), sensitivity (0.613).The RF methods was followed in the AUC of 0.824. Notably, serum IgAN level exerted a significant influence on the models, as revealed by SHAP. Additionally, 167 patients were analyzed for external validation. The AUC of ROC for the external validation of the XGBoost methods were 0.822.
Conclusions : We constructed a non-invasive predictive model for IgAN based on machine learning methods, which can help clinicians achieve real-time prediction and clinical decisions.

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Table 1 Differences in the clinical parameters between IgA nephropathy and non-IgA nephropathy in the training set.

	Total (n=1024)	IgA (n=368)	Non-IgA (n=656)	p-value
Age	40.00(31.00, 53.00)	37.00(29.00, 48.00)	44.00(32.00, 54.00)	<0.001
Sex				0.192
Men	551(53.8)	208(56.5)	343(52.3)	
Women	473(46.2)	160(43.5)	313(47.7)	
Hypertension				0.004
Yes	405(39.6)	167(45.4)	238(36.3)	
No	619(60.4)	201(54.6)	418(63.7)	
Hematuria				<0.001
Yes	609(59.5)	251(68.2)	358(54.6)	
No	415(40.5)	117(31.8)	298(45.4)	
24-h urine protein (g)	2.60(1.30, 5.24)	2.30(1.20, 4.00)	2.80(1.33, 6.80)	<0.001
Serum albumin (g/l)	31.70(23.12, 36.90)	34.40(29.00, 38.15)	29.00(20.00, 36.00)	<0.001
Total cholesterol (mol/l)	5.59(4.50, 7.46)	4.99(4.19, 6.22)	5.91(4.73, 8.50)	<0.001
Triglycerides (mmol/l)	1.81(1.22, 2.74)	1.64(1.15, 2.45)	1.90(1.30, 2.97)	<0.001
HDL cholesterol (mmol/l)	1.29(1.03, 1.63)	1.26(1.01, 1.57)	1.31(1.03, 1.71)	0.015
LDL cholesterol (mmol/l)	3.44(2.59, 4.64)	2.93(2.33, 3.80)	3.66(2.83, 5.39)	<0.001
Serum IgA (g/l)	2.69(1.99, 3.57)	3.20(2.49, 4.17)	2.42(1.84, 3.13)	<0.001
Serum IgG (g/l)	7.80(4.83, 10.40)	9.05(6.40, 11.10)	7.00(4.33, 9.78)	<0.001
Serum IgM (g/l)	0.99(0.70, 7.80)	0.96(0.68, 1.31)	1.00(0.72, 1.40)	0.038
Complement C3 (g/l)	1.13(1.00, 1.30)	1.11(0.97, 1.30)	1.14(1.00, 1.33)	0.017
Uric acid (mmol/l)	388.5(321.25, 459.00)	400.0(330.2, 481.0)	382.5(316.3, 444.5)	0.002
Creatinine (umol/l)	84.25(65.00, 121.80)	97.30(73.90, 148.58)	78.35(61.00, 105.30)	<0.001
Blood Urea nitrogen (mmol/l)	5.98(4.70, 8.14)	6.55(5.00, 8.93)	5.70(4.49, 7.68)	<0.001
eGFR (ml/min/1.73 m^2)	86.80(57.60, 108.52)	72.81(47.63, 98.19)	92.39(65.12, 111.00)	<0.001
Hemoglobin (g/l)	134.00(120.00, 148.00)	132.50(117.25, 147.00)	135.00(122.00 148.00)	0.027

Table 2 Comparison between several machine learning in total population in Internal cohort

	Precision	Sensitivity	Specificity	Accuracy	F1 score	AUC
LR	0.692	0.482	0.867	0.720	0.568	0.818
Random Forest	0.727	0.571	0.867	0.754	0.640	0.824
XGBoost	0.720	0.613	0.852	0.761	0.662	0.831
KNN	0.634	0.506	0.819	0.699	0.563	0.742
Decision tree	0.640	0.613	0.786	0.720	0.626	0.719
SVM	0.724	0.423	0.900	0.718	0.534	0.816

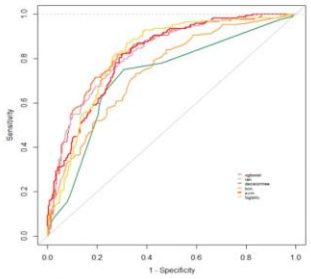

Figure 1 Receiver operating characteristic curves of different prediction models.

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Table 3 Comparison between several machine learning in total population in external cohort

	Precision	Sensitivity	Specificity	Accuracy	F1 score	AUC
LR	0.667	0.390	0.886	0.703	0.492	0.811
Random Forest	0.724	0.512	0.886	0.748	0.600	0.821
XGBoost	0.711	0.659	0.843	0.775	0.684	0.822
KNN	0.632	0.293	0.900	0.676	0.400	0.691
Decision tree	0.659	0.659	0.800	0.748	0.659	0.673
SVM	0.722	0.317	0.929	0.703	0.441	0.749

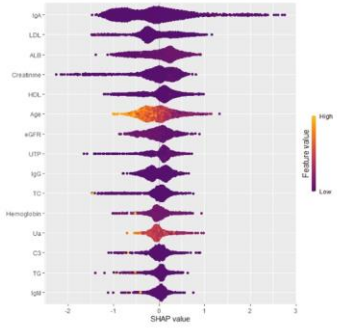
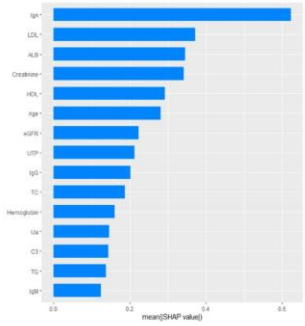


Figure 2 Relative importance of predictors of IgA nephropathy based on SHAP



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