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Applicability of Mayo's Autosomal Dominant Polycystic Kidney Disease (ADPKD) Prognostic Tool in the Southeast Asian ADPKD Population

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Abstract

Autosomal dominant polycystic kidney disease (ADPKD) is a genetic disorder characterised by progressive cyst growth leading to loss of kidney function. The Mayo Clinic ADPKD prognostic tool stratifies patients by risk of progression based on height-adjusted total kidney volume (HtTKV) and age. This study evaluated the tool's applicability in Southeast Asians using data from 50 Malaysian ADPKD patients. HtTKV was measured by MRI. Kidney function was estimated by CKD-EPI-based eGFR. The Mayo model eGFR strongly correlated with actual eGFR over 24 months (cc 0.748–0.815, $p < 0.001$). Bland-Altman analysis showed high accuracy with P30 of Mayo eGFR values more than 90% of measured eGFR. Results indicate the Mayo prognostic tool provides accurate disease progression predictions in Southeast Asian ADPKD patients.

Introduction

Autosomal dominant polycystic kidney disease (ADPKD) is the most common inherited kidney disorder, occurring in 1 in 400 to 1 in 1000 live births worldwide.[1] Based on 32nd report of the Malaysian Dialysis and Transplant Registry (MDTR)[2], ADPKD contributed to about 0.5% of incident end-stage kidney disease (ESKD) in Malaysia. The exact prevalence of ADPKD in Malaysia is not known. It is caused by mutations in the PKD1 or PKD2 genes leading to progressive development and enlargement of fluid-filled cysts in the kidneys.[3] Expansion of cysts causes fibrosis and atrophy of normally functioning kidney tissue, resulting in a gradual decline in kidney function in most patients eventually leading to end-stage renal disease (ESRD).[4]

The rate of progression of ADPKD is highly variable between individuals, even within the same family.[5] While some patients progress to ESRD by age 50, others maintain kidney function into late adulthood.[6–8] Accurately predicting disease progression rates in individual patients has important implications for prognosis and clinical management. Patients predicted to have rapid progression may be counselled to pursue more aggressive treatments or enroll in clinical trials of new therapies aimed at delaying progression.

Several potential prognostic biomarkers have been identified in ADPKD, including age of onset, gene mutation type, hypertension, albuminuria, and kidney enlargement.[9,10] Of these, total kidney volume (TKV) measured by medical imaging is one of the strongest independent predictors of future kidney function decline. TKV reflects both kidney enlargement from cyst growth as well as parenchymal kidney tissue loss. Normalising TKV to patient height (height-adjusted TKV or htTKV) allows comparison between patients of different body sizes.[7,11–16]

In 2015, Irazabal et al at Mayo Clinic published a prognostic model that categorized ADPKD patients into 5 subclasses (A-E) based on htTKV and age, with each class predicted to have a distinct rate of kidney function decline over time.[17] This tool was derived using data from large North American and European

ADPKD cohorts. Whether it would provide accurate prognostication in ADPKD populations from other geographic regions is unknown.

The aim of this study was to evaluate the applicability of the Mayo ADPKD prognostic tool in Southeast Asian ADPKD patients. We analysed htTKV, age, and kidney function data in a Malaysian ADPKD cohort to determine if their observed disease progression aligned with the tool's predictions.

Methods

The study aimed to evaluate the applicability of the Mayo Clinic's Autosomal Dominant Polycystic Kidney Disease (ADPKD) Prognostic Tool within the Southeast Asian population, specifically in a tertiary care setting in Malaysia. This was achieved through a 24-month prospective longitudinal study involving a cohort of ADPKD patients. The methods employed in this study were designed to ensure rigorous data collection and analysis, providing a foundation for evaluating the prognostic tool's performance in this specific population.

Sample Collection and Participants Participants were selected using a convenience sampling approach, which involved enrolling patients diagnosed with ADPKD who visited the nephrology department. A total of 50 patients were enrolled, with inclusion criteria based on the diagnosis of ADPKD. The study focused on a diverse demographic, including a median age of 39.5 years and a representation of both genders, with a slight female predominance (54%) and a significant portion of participants being of Chinese ethnicity (60%).

Imaging and Volume Measurement To assess kidney disease progression, a single non-contrasted T2-weighted Magnetic Resonance Imaging (T2W-MRI) kidney scan was utilised. The ellipsoid method was employed to calculate the Average Total Kidney Volume (TKV_0), a critical parameter in ADPKD prognosis, and the parameters were plugged into Web application by Mayo Foundation & Medical Education & Research to generate the predicted eGFR at 12th and 24th months (https://www.mayo.edu/research/documents/pkd-center-adpkd-classification/doc-20094754). This method, chosen for its precision and non-invasiveness, allowed for the detailed observation of kidney morphology and volume changes over the study period.

Blood Sampling and Laboratory Analysis Yearly blood sampling was conducted to monitor the participants' renal function, specifically evaluating the Glomerular Filtration Rate (GFR). Two measures of GFR were utilised: the serum estimated GFR according to the 2009 Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) creatinine equation (eGFR 2009 CKD-EPI) and the eGFR derived from the Mayo ADPKD prognostic tool (eGFR Mayo). These measures provided insights into renal function decline and disease progression among the study population.

Data Analysis Statistical analysis involved correlating the TKV_0 measured from MRI scans with the renal function metrics obtained from blood samples. The Spearman correlation coefficient and Bland-Altman analysis were employed to assess the relationship between eGFR Mayo and eGFR 2009 CKD-EPI at the

beginning of the study, and at 12 and 24 months. This analytical approach allowed for the examination of the prognostic tool's accuracy and reliability in predicting renal outcomes in the ADPKD population.

Results

Baseline Demographics and Clinical Profile Our study cohort of 50 participants represents a relatively young, multi-ethnic population with a pronounced risk profile for rapid disease progression (Refer Table 1). The median age of the cohort was 39.5 years (interquartile range [IQR], 33.5–58.0), with a slight female predominance at 54%. The ethnic distribution predominantly comprising Chinese (60%), followed by Malay (26%) and Indian (14%) patients. Anthropometric baseline values were typical for our local population, demonstrating a median height of 1.63 meters, a median weight of 61.2 kilograms, and a healthy median body mass index (BMI) of 23.0 kg/m² (IQR, 20.8–26.3). This diverse demographic profile provided a broad basis for evaluating the prognostic tool across different age groups and ethnic backgrounds within the Southeast Asian population.

From a clinical and genetic perspective, the cohort exhibited hallmark features of ADPKD, with 74% of participants reporting a positive family history. Despite possessing largely preserved baseline renal function—indicated by a median serum creatinine of 88 μmol/L (IQR, 63–128) and a median eGFR of 83 ml/min/1.73m² (IQR, 46–110). Of note, 68% of patients had baseline eGFR of more than 60 ml/min/1.73m^2.

The study embarked on an evaluation of the Mayo Clinic's ADPKD Prognostic Tool within this cohort representing Southeast Asian population, focusing on the distribution of height-adjusted total kidney volume (htTKV), the frequency of different ADPKD subclasses, and the slopes of estimated glomerular filtration rate (eGFR) over a period of 24 months (Fig. 1; Fig. 2; Table 2; Table 3).

When stratified by the Mayo ADPKD Imaging Classification, the majority of the cohort was categorized into rapid-progression phenotypes. Specifically, 62% of the patients were designated into the high-risk classes of 1C (26%), 1D (20%), and 1E (16%), while the remainder fell into Class 1B (24%) and 1A (14%). Among the 62% with high-risk classes (1C-1E), 71.0% had baseline eGFR of more than 60 ml/min/1.73m^2. This structural severity was accompanied by expected early hemodynamic changes, with a mean systolic and diastolic blood pressure of 135.9 ± 17.4 mmHg and 79.8 ± 11.0 mmHg, respectively. Additionally, baseline proteinuria was modest, showing a median urine protein-creatinine ratio of 13.0 mg/mmol (IQR, 7.7–43.4) among 45 evaluated patients, and a median spot urine osmolality of 400 mOsm/kg (IQR, 258–581) in a subset of 27 patients.

Kidney Volume and htTKV Distribution. The Average Total Kidney Volume (TKV_0), measured using the ellipsoid method from T2-weighted MRI scans, revealed significant variability in kidney size among participants, indicating the heterogeneity of disease progression within the cohort. The median total kidney volume (TKV) was substantially enlarged at 1233.8 cm³ (IQR, 697.2–1995.8). This translated to a median height-adjusted total kidney volume (htTKV) of 727.9 ml/m (IQR, 447.0–1180.9). This indicated

the significant variability in kidney size within our patient population, reflecting the diverse stages of ADPKD progression within the cohort. This variation underscores the heterogeneity of the disease progression among individuals, aligning with the expectation that ADPKD manifests with variable severity and at different rates of kidney volume increase over time.

Correlation of eGFR Measurements

A critical aspect of our analysis focused on the correlation between the eGFR as estimated by the Mayo ADPKD Prognostic Tool and the eGFR calculated using the 2009 CKD-EPI creatinine equation. Our findings demonstrate a strong correlation between these two measures of renal function over the study duration (based on Fig. 1 to 3), with a statistically significant p-value of < 0.001. This strong correlation underscores the prognostic tool's capability to accurately reflect changes in renal function in ADPKD patients.

The comparison of GFR slopes to the Mayo model’s predictions confirms the tool’s robustness in reflecting the renal functional decline over time. The study’s findings indicate that the Mayo ADPKD Prognostic Tool is not only applicable but also a reliable indicator of disease progression in the Southeast Asian ADPKD population, mirroring the GFR slopes with high precision and low bias.

Accuracy and Reliability

This study demonstrated the Mayo ADPKD Prognostic Tool's high level of accuracy and reliability in the Southeast Asian ADPKD population. The prognostic tool's predictions were evaluated for accuracy against eGFR values based on 2009 CKD-EPI equation. Based on our analysis revealed that the eGFR estimates derived from the Mayo model demonstrated acceptable degree of bias, precision, and accuracy. The generated bias was less than 5 ml/min/1.73m^2 mean difference with an acceptable precision of IQR of less than 15ml/min/1.73m^2. We used P30 for accuracy interpretation, defined as the percentage of estimates within 30% of the measured GFR used in the Mayo Classification. KDOQI[18] mandates a P30 value of ≥ 90% for an equation to be deemed ready for routine clinical use. The P30 values had exceeded 90% as detailed in Table 2 and Table 3, with the exception at 24 months as 3 patients were excluded from analysis due to missing data. This highlights that the Mayo prediction tool has high level of precision in forecasting renal function outcomes for most of the study period.

Table 1
Patient demographics. Values are expressed in number (%), mean ± standard deviation, and median (interquartile range) when appropriate.

BASELINE CHARACTERISTICS	VALUES
N	50
Age (years), IQR	39.5 (33.5–58.0)
Gender, n (%)	
Male	23 (46)
Female	27 (54)
Ethnicity, n (%)	
Malay	13 (26)
Chinese	30 (60)
Indian	7 (14)
Height, metre, IQR	1.63 (1.58–1.70)
Weight, kilograms, IQR	61.2 (56.2–72.7)
BMI, kgm^2, IQR	23.0 (20.8–26.3)
Total Kidney Volume, cm^3, IQR	1233.8 (697.2-1995.8)
Height Adjusted Total Kidney Volume (HtTKV), ml/m, IQR	727.9 (447.0-1180.9)
$Creatinine_0$, µmol/L, IQR	88 (63–128)
$eGFR_0$ (EPI-CKD), ml/min/1.73m^2, IQR	83 (46–110)
Urine Protein-Creatinine $Ratio_{0,}$ mg/mmol (n = 45), IQR	13.0 (7.7–43.4)
Urine $Osmolality_{0\ ,}$ mOsm/kg (n = 27), IQR	400 (258–581)
Systolic Blood Pressure, mmHg	135.9 *± 17.4*
Diastolic Blood Pressure, mmHg	79.8 ± 11.0
Family History, n (%)	
Yes	37 (74)
No	13 (26)
Mayo ADPKD Classification, n (%)	1A: 7 (14) 1B: 12 (24) 1C: 13 (26) 1D 10 (20) 1E: 8 (16)

BASELINE CHARACTERISTICS	VALUES
High Risk Class (1C,1D,1E), n (%)	31 (62)

Table 2
Bland-Altman analysis of correlation between glomerular filtration rate generated from the Mayo ADPKD prognostic tool (eGFRMayo) and serum estimated glomerular filtration rate of patients according to 2009 CKD-EPI (eGFR2009CKD-EPI)

Groups	n	r_s	p-value	Bias (Mean difference)	Precision (SD of Mean Difference)	Accuracy (P30) ,%
$eGFR_{Mayo}$ vs $eGFR_{2009CKD-EPI}$ **at 0 month**	50	1.000	0.000	0.196	0.395	98
$eGFR_{Mayo}$ vs $eGFR_{2009CKD-EPI}$ **at 12 months**	50	0.972	0.000	0.204	8.300	90
$eGFR_{Mayo}$ vs $eGFR_{2009CKD-EPI}$ **at 24 months**	47	0.952	0.000	-4.670	10.930	85.1

Table 3
Spearman’s rank correlation coefficient and Bland-Altman analysis

Variables	n	Spearman’s rank correlation coefficient (R_s)	p-value	Bias (Mean difference)	Precision (± 1.96SD of Mean Difference)	Accuracy (P30) ,%
$eGFR_{Mayo}$ vs $eGFR_{2009CKD-EPI}$ at 0 month	50	1.000	0.000	-0.196	0.395	98
$eGFR_{Mayo}$ vs $eGFR_{2009CKD-EPI}$ at 12 months	50	0.972	0.000	-0.204	8.300	90
$eGFR_{Mayo}$ vs $eGFR_{2009CKD-EPI}$ at 24 months	47	0.952	0.000	4.670	10.930	85.1

GFR Slopes Compared to the Mayo Model: The study found a very strong correlation between the GFR estimated by the Mayo ADPKD Prognostic Tool (eGFR Mayo) and the GFR calculated using the 2009 CKD-EPI creatinine equation (eGFR 2009CKD-EPI), suggesting that the Mayo model's predictions are highly applicable to the Southeast Asian population. This correlation was evidenced by Spearman

correlation coefficients and supported by Bland-Altman analysis, demonstrating the tool's accuracy and reliability in estimating GFR slopes over the study period. When we analyse this cohort based on eGFR decline for each Mayo classification (refer Table 4), the mean eGFR decline (ml/min/1.73m^2/year) was: 5.3 (1A), 2.8 (1B), 4.4 (1C), 9.8 (1D) and 8.9 (1E). The percentage of patients with eGFR decline ≥ 3 ml/min/1.73m^2/year based on each class was: 71.4% (1A), 41.7% (1B), 69.2 (1C), 90.0 (1D) and 100% (1E). Patients with high-risk classes (1C-1E) had higher mean eGFR decline compared to low-risk classes (1A-1B) and higher percentages of having eGFR decline ≥ 3 ml/min/1.73m^2/year, which is one of the criteria for selection of patients for Tolvaptan. Nevertheless, it is worth mentioning that patients in Mayo class 1A also had significant mean eGFR decline per year (5.3 ml/min/1.73m^2) with 71.4% of them had eGFR decline ≥ 3 ml/min/1.73m^2/year. This could be due to small sample size (N = 7) and variability of the eGFR readings, thus this finding may not able to tell if class 1A patients have any significant risk of ADPKD progression.

Table 4

Mean eGFR decline and percentage of eGFR decline ≥ 3 ml/min/1.73m^2 based on different subcategory of Mayo classification

Mayo Classification	N	Mean eGFR decline (ml//min/1.73m^2/year)	Percentage of eGFR decline ≥ 3 ml/min/1.73m^2/year (%)
Class 1A	7	5.3	71.4
Class 1B	12	2.8	41.7
Class 1C	13	4.4	69.2
Class 1D	10	9.9	80.0
Class 1E	8	8.9	100.0

Discussion

Drawing on the detailed analysis of the Mayo Clinic's Autosomal Dominant Polycystic Kidney Disease (ADPKD) Prognostic Tool's applicability to the Southeast Asian population, specifically within a Malaysian cohort, we delve into a comprehensive discussion on the implications, strengths, and limitations of our findings, as well as proposed directions for future research.

Existing Literatures on Mayo Imaging Classification (MIC)

The Mayo Imaging Classification (MIC) was initially built and validated predominantly on Western and Caucasian cohorts. There were three published literatures in East Asia countries which successfully bridge this gap, confirming that the mathematical assumption behind the MIC hold true for East Asian population. Park et al (2022)[19] published the KNOW-CKD study from Korean cohort. It comprised of 178 adult ADPKD patients who were followed prospectively for an average of 6.2 years. 61.8% of the cohort

fell into the rapid progressor category (MIC classes 1C, 1D and 1E). These patients were significantly younger, predominantly male and had notable accelerated measured htTKV growth rate per year (5.3% for 1C, 9.4% for 1D, 11.7% for 1) as compared to slow progressors (1.2% for 1A and 3.8% for 1B). Rapid progressors also had 4-fold higher risk of adverse renal outcomes. Higashihara et al (2019)[20] reported on Japanese cohort of 296 ADPKD patients, with 88 of them had fully characterised PKD mutations. It showed that a single baseline htTKV strongly correlated with earlier symptoms onset and a steeper decline in eGFR than tracking brief longitudinal changes. Fung et al (2024)[21] reported on Hong Kong cohort of 98 ADPKD patients. There were 17.3% of the Chinese cohort who displayed atypical polycystic imaging presentations, which nearly doubled the 8.8% historical prevalence reported in Western or Caucasian cohorts by the Mayo Clinic. Patients with atypical patterns experienced a much milder phenotype, significantly older at the time of diagnosis and required blood pressure medications later in life. The typical imaging group had a steep eGFR decline of -3.44ml/min/1.74m^2 per year, as compared to atypical imaging with eGFR decline of -0.86ml/min/1.73m^2 per year ($p = 0.02$). Nevertheless, patients with typical imaging of ADPKD confirmed that mathematical assumptions behind the MIC still hold true for East Asian genetics and physiology. However, there is limited data with regards to Malaysian population based on available literature.

Clinical Implications in Southeast Asia

Our study confirms the Mayo Clinic's ADPKD Prognostic Tool's effectiveness in accurately stratifying risk and predicting the rate of GFR decline in Southeast Asian patients. This achievement underscores the prognostic model's robustness and its capacity to generalise across diverse racial and ethnic populations, extending beyond its original North American and European cohorts to include Malaysian patients.

The applicability of the tool in Southeast Asia has profound clinical implications. It offers a reliable means for healthcare providers to counsel ADPKD patients on their anticipated disease progression, thereby informing management decisions. Specifically, patients classified into subclasses indicating rapid progression (Mayo class 1D-E) can be a potential candidate for Tolvaptan use or considered for enrolment in clinical trials aimed at delaying disease progression. In our local settings, Tolvaptan is available as the proven therapy to delay progression of kidney function. However, the barrier would be high treatment cost and most patients would need to purchase it out-of-pocket. The risk stratification tool can therefore assist in selecting patients who are high-risk and make shared decision making regarding the available therapy. Conversely, those predicted to experience a slower disease course (class 1A) may benefit from reassurance and a conservative management approach, avoiding unnecessary treatments and their associated risks.

Validation and Generalisability

While our findings are promising, they should be viewed in light of the study's limitations. The sample size of 50 patients, though sufficient for preliminary validation, necessitates further investigation in larger, more diverse Southeast Asian populations to ascertain the model's full applicability and accuracy. Moreover, our study's relatively short follow-up period of 24 months provides a snapshot of the disease progression trajectory that may not capture the full spectrum of ADPKD progression over the longer term. Future studies with extended follow-up durations are essential to observe the long-term validity of the Mayo model's predictions.

Future Research Directions

The positive outcomes of this study advocate for expanded validation efforts of the Mayo ADPKD Prognostic Tool within different subregions of Asia, encompassing a broader array of genetic backgrounds and environmental factors that may influence ADPKD progression. Additionally, investigating the tool's performance in predicting other clinically relevant outcomes, such as the onset of hypertension, renal pain, and the development of renal insufficiency, could further enhance its utility in clinical practice.

Conclusion

In summary, our study contributes valuable evidence supporting the Mayo Clinic's ADPKD Prognostic Tool as a versatile and reliable instrument for risk stratification and disease progression prediction in Southeast Asian ADPKD patients. Its clinical integration can significantly impact patient counselling, management strategies, and the identification of candidates for therapeutic interventions aimed at slowing disease progression. Acknowledging the need for further validation, our research lays the groundwork for future explorations to solidify the tool's role in the global management of ADPKD, fostering a more informed and tailored approach to patient care.

Declarations

Conflict of interest disclosures:

None

Contributor statement

C.C.G. conceived and designed the study; C.C.G., E.T.G, S.H.O, W.L.L, P.L.C., and A.V. collected the data. C.C.G. and J.Q.T. were involved in the data analysis; C.C.G and J.Q.T. wrote the manuscript; J.M.E, S.K.L. and A.V. critically revised the manuscript. All authors have read and approved the final manuscript.

Ethics Approval and Consent to Participate Declaration

Informed consent was obtained from all individual participants included in the study. All procedures performed in studies involving human participants were in accordance with the ethical standards of the Medical Research Ethics Committee (MREC), University of Malaya Medical Centre and approved under the approval number 2018615-6398, in accordance with the Declaration of Helsinki 1964 and its later amendments or comparable ethical standards.

Consent for Publication

Not applicable, as this manuscript does not contain any individual person's personally identifiable data, images, or videos.

Funding Declaration

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Author Contribution

C.C.G. conceived and designed the study; C.C.G., E.T.G, S.H.O, W.L.L, P.L.C., and A.V. collected the data. C.C.G. and J.Q.T. were involved in the data analysis; C.C.G and J.Q.T. wrote the manuscript; J.M.E, S.K.L. and A.V. critically revised the manuscript. All authors have read and approved the final manuscript.

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Data Availability

The datasets generated and/or analysed during the current study are not publicly available due institutional policy but are available from the corresponding author on reasonable request.

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Figures

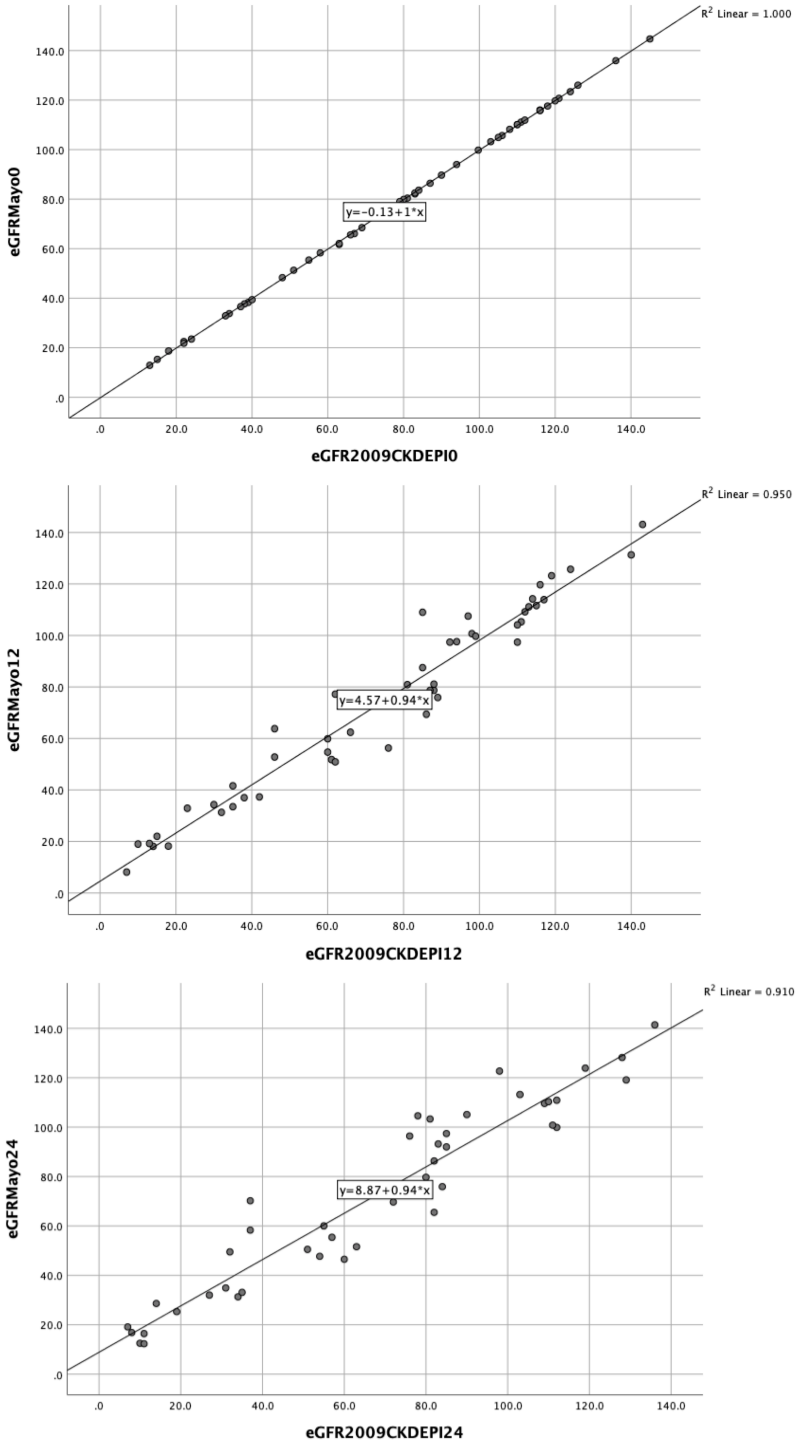

Figure 1

Correlation coefficient between eGFR(Mayo) and eGFR2009(CKD-EPI) for month 0, 12, and 24.

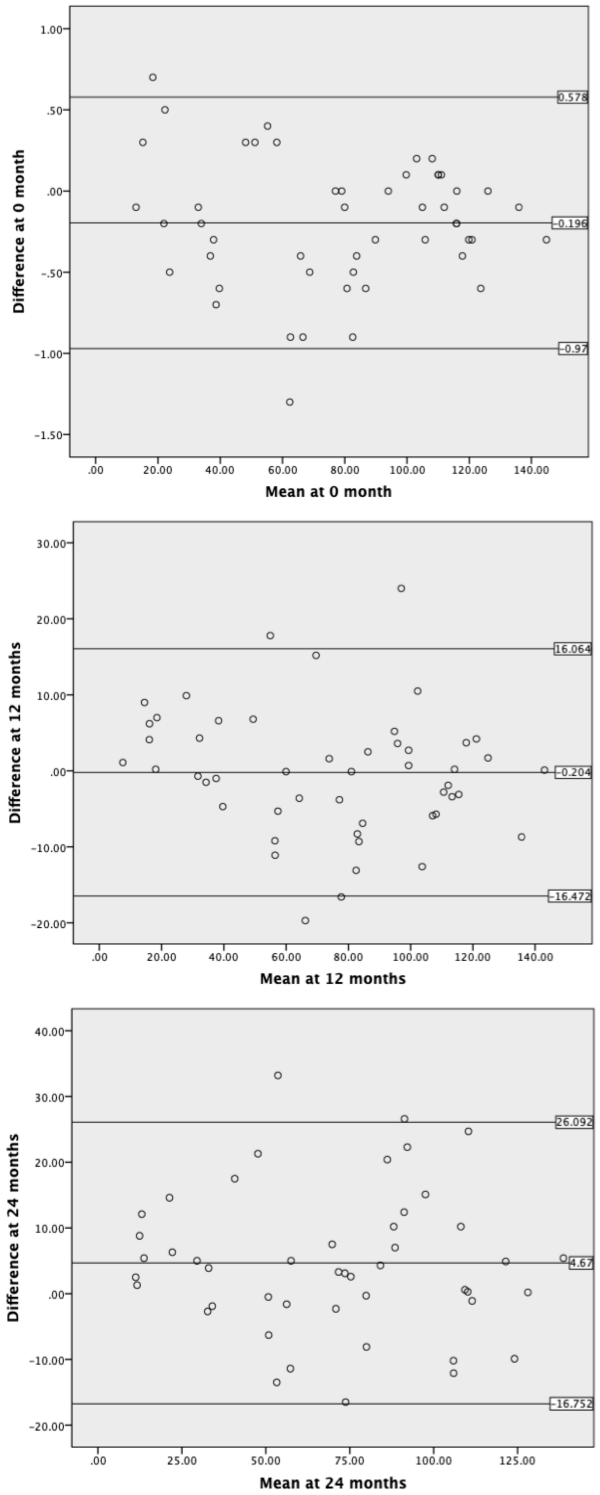

Figure 2

Bland-Altman analysis of eGFR(Mayo) and eGFR (2009CKD-EPI) at month 0, 12, and 24.