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CLINICAL & BASIC RESEARCH

Comparison between Three Different Equations for the Estimation of Glomerular Filtration Rate in Omani Patients with Type 2 Diabetes Mellitus

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مقارنة أداء ثلاثة معادلات مختلفة تستخدم للحصول على تقدير سرعة الترشيح الكبيبي لدى المرضى العمانيين المصابين بداء السكري من النوع الثاني

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ABSTRACT: ***Objectives:*** Estimated glomerular filtration rate (eGFR) is an important component of a patient's renal function profile. The Modification of Diet in Renal Disease (MDRD) equation and the Chronic Kidney Disease-Epidemiology Collaboration (CKD-EPI) equation are both commonly used. The aim of this study was to compare the performance of the original $MDRD_{186}$, revised $MDRD_{175}$ and CKD-EPI equations in calculating eGFR in type 2 diabetes mellitus (T2DM) patients in Oman. ***Methods:*** The study included 607 T2DM patients (275 males and 332 females, mean age ± standard deviation 56 ± 12 years) who visited primary health centres in Muscat, Oman, during 2011 and whose renal function was assessed based on serum creatinine measurements. The eGFR was calculated using the three equations and the patients were classified based on chronic kidney disease (CKD) stages according to the National Kidney Foundation Kidney Disease Outcomes Quality Initiative guidelines. A performance comparison was undertaken using the weighted kappa test. ***Results:*** The median eGFR (mL/min/1.73 m^2) was 92.9 for $MDRD_{186}$, 87.4 for $MDRD_{175}$ and 93.7 for CKD-EPI. The prevalence of CKD stage 1 was 55.4%, 44.7% and 57% while for stages 2 and 3 it was 43.2%, 54% and 41.8%, based on $MDRD_{186}$, $MDRD_{175}$ and CKD-EPI, respectively. The agreement between $MDRD_{186}$ and CKD-EPI (κ 0.868) was stronger than $MDRD_{186}$ and $MDRD_{175}$ (κ 0.753) and $MDRD_{175}$ and CKD-EPI (κ 0.730). ***Conclusion:*** The performances of $MDRD_{186}$ and CKD-EPI were comparable. Considering that CKD-EPI-based eGFR is known to be close to isotopically measured GFR, the use of $MDRD_{186}$ rather than $MDRD_{175}$ may be recommended.

Keywords: Diet Modification; Chronic Renal Insufficiency; Epidemiology; Collaboration; Glomerular Filtration Rates; Type 2 Diabetes Mellitus; Oman.

الملخص: **الهدف**: يعتبر تقدير معدل الترشيح الكبيبي (eGFR) من أهم وسائل تقييم وظائف الكلى. وتستخدم سريريا معادلتان لتقدير هذا المعدل، الأولى هي معادلة تعديل النمط الغذائي في أمراض الكلى (MDRD) والأخرى هي المعادلة المستخلصة من دراسة وبائيات أمراض الكلى المزمنة (CKD-EPI). إن هدف هذه الدراسة هو مقارنة أداء المعادلة الأصلية ($MDRD_{186}$) ونسختها المعدلة ($MDRD_{175}$) مع أداء المعادلة (CKD-EPI) عند المرضى المصابين بداء السكري في عمان. **الطريقة**: شملت الدراسة 607 مرضى بالسكري من النوع الثاني (332 إناث و275 ذكور) أعمارهم في المتوسط مع انحراف معياري يبلغ 12 ± 56 عاما مسجلين في المراكز الصحية الأولية في مسقط بسلطنة عمان خلال عام 2011م، وتم تقييم وظائف الكلى عندهم باستخدام تركيز الكرياتنين في الدم. تم في هذا البحث قياس معدل الترشيح الكبيبي باستخدام ثلاث معادلات، وتم أيضا تصنيف حالة المرض الكلوي المزمن (CKD) عند هؤلاء المرضى بحسب معايير مؤسسة أمراض الكلي فيما يتعلق بنتائج مبادرات الجودة. **النتائج**: وجد أن وسيط eGFR للمعادلات الثلاث كان كالتالي بالنسبة إلى $MDRD_{186}$ كان المعدل هو 92.9 مل دقيقة/1.73م^2، و بالنسبة إلى $MDRD_{175}$ كان المعدل هو 87.4 مل دقيقة/1.73م^2، و بالنسبة إلى CKD-EPI كان المعدل 93.7 مل دقيقة/1.73م^2. ووجد أن معدل انتشار مرحلة CKD الأولى كان 55.4%، 44.7%، و 57% ، في حين كان للمرحلة الثانية والثالثة 43.2%، 54% و 41.8% لكل من $MDRD_{186}$، $MDRD_{175}$ وCKD-EPI على التوالي. كما لوحظ أن الاتفاق بين معادلتي ($MDRD_{186}$ وCKD-EPI) كان أقوى من الاتفاق بين ($MDRD_{186}$ و$MDRD_{175}$) و ($MDRD_{175}$ وCKD-EPI). **الخلاصة**: وجد في هذه الدراسة أن أداء معادلتي $MDRD_{186}$و EPI-CKD-EPI لتقدير GFR كان متقاربا جدا بالمقارنة مع $MDRD_{175}$و CKD. EPI، و للتقليل من معدل زيادة تشخيص مراحل أمراض الكلى المزمن CKD من المستحسن إعادة النظر في استخدام أفضلية $MDRD_{186}$ وتقارب تقدير GFR مع CKD-EPIمقارنة ب $MDRD_{175}$.

مفتاح الكلمات: تعديل النظام الغذائي؛ القصور الكلوي المزمن؛ الوبائيات؛ التعاون؛ معدل الترشيح الكبيبي؛ داء السكري من النوع الثاني؛ عمان.

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Advances in Knowledge

- *Several estimated glomerular filtration rate (eGFR) equations have been implemented and updated in clinical practice for improving diagnostic care in renal medicine.*
- *This study examines the impact of different eGFR equations on the prevalence of chronic kidney disease (CKD) in diabetic patients attending primary health centres in Muscat, Oman. The most effective is the Modification of Diet in Renal Disease (MDRD) equation $MDRD_{186}$ rather than $MDRD_{175}$.*

Application to Patient Care

- *eGFR in renal profiles facilitates the early detection of renal impairment which will allow for early therapy in diabetic patients.*
- *eGFR equations yield comparable results in established CKD (stage 4 and 5); however, the results are usually variable in early CKD (stages 1, 2 and 3).*
- *This study provides data indicating that the most appropriate eGFR equation for the classification of CKD in diabetic patients is $MDRD_{186}$ rather than $MDRD_{175}$.*

Serum creatinine-based equations for calculating estimated glomerular filtration rate (eGFR) have an established role in the assessment of renal function; these equations have improved the detection and management of chronic kidney disease (CKD), particularly in the last decade. The eGFR relates better to kidney function than serum creatinine, which is less useful as a single criterion of kidney function.[1,2] Several equations are available for the calculation of eGFR, with the most commonly used ones being the Cockroft-Gault formula (1976), the Modification of Diet in Renal Disease (MDRD) equation (1999) and the Chronic Kidney Disease-Epidemiology Collaboration (CKD-EPI) equation (2009).[3]

In order to calculate the eGFR, the Cockcroft-Gault formula requires serum creatinine levels, age, gender and weight.[4] It was originally based on the 1886 Jaffe assay for creatinine measurement; hence, it should be interpreted cautiously when the new creatinine methods are used. The need for weight and body surface area correction has limited its routine implementation.[5] The MDRD equation is based on serum creatinine measurements, age and gender. In addition, it takes into account ethnicity (for African Americans) with results adjusted to a body surface area of 1.73 m^2.[6–9] It is a popular equation that has been adopted for the classification of CKD in clinical practice by many international entities.[1,7,8] Moreover, in 2006 the Department of Health in England recommended all National Health Service laboratories to report eGFR based on MDRD with every serum creatinine result, with a similar approach being adopted in North America, Europe and Australia.[5,10,11]

In the original MDRD equation ($MDRD_{186}$), a constant factor of 186 was used which was later revised and re-expressed by the same authors, Levey *et al*., to a constant factor of 175 ($MDRD_{175}$). This was mainly due to the standardisation of creatinine assays against the isotope dilution-mass spectrometry reference method.[7–9] The MDRD equation works reasonably well at eGFR ≤60 mL/min/1.73 m^2, but underestimates GFR in subjects with a GFR ≥60 mL/min/1.73 m^2; thus, it has limited accuracy in this range.[9] However, despite the improved standardisation of the creatinine assay, this limitation did not improve when using the new revised $MDRD_{175}$ as compared to the gold-standard isotopically-based method.[12] The MDRD equation was revisited again by Levey *et al*. in 2009, who then derived a new equation, the CKD-EPI equation.[12] This new equation appears to be more accurate in estimating the GFR in the range of low serum creatinine. It yields GFR values with better agreement for eGFR than MDRD when compared with radio-labelled methods.[12,13]

The objective of this study was to compare the performance of the original $MDRD_{186}$, revised $MDRD_{175}$ and CKD-EPI equations for the calculation of eGFR, and their impact on classifying CKD stages in patients with type 2 diabetes mellitus (T2DM) attending primary health centres (PHCs) in Muscat, Oman.

Methods

This retrospective study was based on data from patients' electronic records. All adult Omani T2DM patients registered in PHCs were considered candidates for inclusion in the study. The process involved multi-stage random selection of PHCs followed by the random selection of patients. The data were mainly for Omani adult patients aged ≥25 years who were diagnosed with T2DM between 1 January and 31 December 2011 (N = 607). The data included information such as age, gender, weight, height, duration of diabetes mellitus (DM), medications and serum creatinine levels. All duplicate tests were subsequently excluded. For those patients with more than one reported creatinine result, the most recent value was taken for analysis. Ethical approval for

Table 1: Serum creatinine-based formulae for the calculation of estimated glomerular renal filtration rate

MDRD formulae:
Original four-variable $MDRD_{186}$ formula[7]:
eGFR (mL/min/1.73 m^2) = 186 (S.Cr in µmol/L x 0.011312)$^{-1.154}$ x (age)$^{-0.203}$ x (0.742 if female) x (1.212 if African American/black)
***Revised four-variable $MDRD_{175}$ formula[9]:**
eGFR (mL/min/1.73 m^2) = 175 (S.Cr in µmol/L x 0.011312)$^{-1.154}$ x (age)$^{-0.203}$ x (0.742 if female) x (1.212 if African American/black)
CKD-EPI formulae[12]:
For female with Cr <62 µmol/L:
eGFR (mL/min/1.73 m^2) = 144 x (Cr/61.6)$^{-0.329}$ x (0.993)^{age}
For female with Cr >62 µmol/L:
eGFR (mL/min/1.73 m^2) = 144 x (Cr/61.6)$^{-1.209}$ x (0.993)^{age}
For male with Cr <80 µmol/L:
eGFR (mL/min/1.73 m^2) = 141 x (Cr/79.2)$^{-0.411}$ x (0.993)^{age}
For male with Cr >80 µmol/L:
eGFR (mL/min/1.73 m^2) = 141 x (Cr/79.2)$^{-1.209}$ x (0.993)^{age}

MDRD = modification of diet in renal disease; eGFR = estimated glomerular filtration rate; S.Cr = serum creatinine; CKD-EPI = chronic kidney disease-epidemiology; Cr = creatinine.

**Recommended for creatinine assay standardised against isotope dilution-mass spectrometry.*

the study was obtained from the Ministry of Health Research and Ethical Review & Approval Committee in December 2011.

For all patients, the laboratory measurement of serum creatinine was performed using a Synchron LX20 analyser (Beckman Coulter, Inc., Brea, California, USA). Serum creatinine was analysed by the kinetic alkaline picrate methodology which is traceable to the reference method based on isotope dilution-mass spectrometry (IDMS). For each patient, eGFR was calculated using $MDRD_{186}$, $MDRD_{175}$ and CKD-EPI [Table 1]. A factor of 1.0 was considered for ethnicity since no evidence was available for a correction factor related to the local population being studied, and there were no participants of African American ethnicity to allow the use of the factor 1.212.[7–9] The patients were classified according to their eGFR values (in mL/min/1.73 m^2) into five CKD stages as per the National Kidney Foundation Kidney Disease Outcomes Quality Initiative guidelines: normal or CKD stage 1 - eGFR ≥90; CKD stage 2 - eGFR 60–89; CKD stage 3 - eGFR 30–59; CKD stage 4 - eGFR 15–29, and CKD stage 5 - eGFR <15.[10]

The data for each PHC was entered separately using Microsoft Excel (Microsoft Corp., Redmond, Washington, USA). A final integrated Excel worksheet was exported to the Statistical Package for the Social Sciences (SPSS), Version 16 (IBM, Corp., Chicago, Illinois, USA) for final analysis. The demographic and clinical data were expressed as mean, median, standard deviation (SD) and range (minimum–maximum). For calculating the prevalence, a pre-determined cut-off value was used to identify the abnormal levels which had been taken from the international guidelines for each parameter. The number of abnormal results were divided by the population size in that group and then multiplied by 100 to yield the prevalence percentage. A comparison between the CKD stages calculated from the three eGFR equations was undertaken using the weighted kappa test for agreement: a kappa statistic (κ) of 0.21–0.40 was considered fair agreement; 0.41–0.60 a moderate agreement; 0.61–0.80 a substantial agreement, and 0.81–1.00 a near-perfect agreement.[14]

Table 2: Different parameters in the diabetic population (N = 607)

Variables	Median	Mean ± SD	Range
Age in years	56.0	56.1 ± 12.5	26–92
Creatinine in µmol/L	71.0	75.7 ± 32.0	33–399
$MDRD_{186}$ in mL/min/1.73 m^2	92.9	93.8 ± 27.6	13–188
$MDRD_{175}$ in mL/min/1.73 m^2	87.4	88.3 ± 25.9	13–177
CKD-EPI in mL/min/1.73 m^2	93.7	89.3 ± 21.3	11–131

SD = standard deviation; MDRD = modification of diet in renal disease; CKD-EPI = chronic kidney disease-epidemiology.

Results

The patients in this study (N = 607) included 275 males (45.3%) and 332 females (54.7%) aged 26–92 years with a mean age ± SD of 56 ± 12 years. They had a mean DM duration of 6.9 ± 0.2 years, a body mass index of 30 ± 0.34, a glycated haemoglobin (HbA_{1C}) level of 8 ± 0.09 and an albumin-to-creatinine ratio of 8.8 ± 1.97. The median value for serum creatinine (µmol/L) was 71 (range 33–339) and the eGFR (mL/min/1.73 m^2) was 92.9 for $MDRD_{186}$, 87.4 for $MDRD_{175}$ and 93.7 for CKD-EPI [Table 2].

The distribution of CKD stages based on the three

Table 3: Prevalence of chronic kidney disease stages based on eGFR by MDRD and CKD-EPI formulae (N = 607)

eGFR in mL/min/1.73 m^2	$MDRD_{186}$ n (%)	$MDRD_{175}$ n (%)	CKD-EPI n (%)
≥90	337 (55.4)	271 (44.7)	346 (57)
60–89	213 (35.1)	257 (42.3)	197 (32.5)
30–59	49 (8.1)	71 (11.7)	56 (9.3)
15–29	7 (1.2)	6 (1.0)	6 (1.0)
<15	1 (0.2)	2 (0.3)	2 (0.3)

eGFR = estimated glomerular filtration rate; MDRD = modification of diet in renal disease; CKD-EPI = chronic kidney disease-epidemiology.

Table 4: Comparison of the prevalence of chronic kidney disease stages based on eGFR by $MDRD_{186}$ as compared with $MDRD_{175}$ and CKD-EPI formulae in the study patients (N = 607)

	eFGR in mL/min/1.73 m²	$MDRD_{186}$ n (%)						
		≥90	60–89	30–59	15–29	<15	Total	κ
$MDRD_{175}$	**≥90**	271 (80)	-	-	-	-	271	
	60–89	66 (20)	191 (87)	-	-	-	257	
	30–59	-	22 (10.3)	49 (100)	-	-	71	**0.753**
	15–29	-	-	-	6 (86)	-	6	
	<15	-	-	-	1 (14)	1 (100)	2	
	Totals	**337**	**213**	**49**	**7**	**1**	**607**	
CKD-EPI	**≥90**	324 (96)	22 (10.3)	-	-	-	346	
	60–89	13 (4)	183 (85.9)	1 (2)	-	-	197	
	30–59	-	8 (3.8)	48 (98)	-	-	56	**0.868**
	15–29	-	-	-	6 (86)	-	6	
	<15	-	-	-	1 (14)	1 (100)	2	
	Totals	**337**	**213**	**49**	**7**	**1**	**607**	

eGFR = estimated glomerular filtration rate; MDRD = modification of diet in renal disease; κ = kappa statistic; CKD-EPI = chronic kidney disease-epidemiology.

equations is shown in Table 3. Of the diabetic patients screened, 90.5%, 87% and 89.5% had an eGFR of ≥60 mL/min/1.73 m² (CKD stages 1 and 2) and 9.5%, 13% and 10.5% had an eGFR of <60 mL/min/1.73 m² (CKD stages 3, 4 and 5) based on $MDRD_{186}$, $MDRD_{175}$ and CKD-EPI equations, respectively. The difference mainly involved CKD stages 1, 2 and 3. The distribution of patients was nearly the same between the three equations in CKD stages 4 and 5.

Based on the weighted kappa analysis (κ 0.753), the agreement between $MDRD_{186}$ and $MDRD_{175}$ was found to be considerable. The $MDRD_{175}$ overestimated 66 (19.6%) and 22 (10.3%) patients as CKD stages 2 and 3, respectively, who had been labelled as CKD stages 1 and 2, respectively, using $MDRD_{186}$. The $MDRD_{186}$ and CKD-EPI showed near-perfect agreement (κ 0.868). There were 13 (3.9%) and 8 (3.8%) patients with CKD stages 1 and 2 using $MDRD_{186}$ who were reclassified into CKD stage 2 and 3 by CKD-EPI, respectively. On the other hand, 22 patients (10.3%) with CKD stage 2 using $MDRD_{186}$ were reclassified as CKD stage 1 using CKD-EPI [Table 4]. The agreement between $MDRD_{186}$ and CKD-EPI (κ 0.868) was better than between $MDRD_{175}$ and CKD-EPI (κ 0.730). There was also a clear underestimation of GFR using $MDRD_{175}$ compared to CKD-EPI and $MDRD_{186}$ for patients with eGFR ≥60 mL/min/1.73 m². CKD-EPI reclassified 79 (30.7%) patients from CKD stage 2 using $MDRD_{175}$ into CKD stage 1, and another 15 (21.1%) patients were reclassified as CKD stage 2 from stage 3

Table 5: Comparison of the prevalence of chronic kidney disease stages based on eGFR by $MDRD_{175}$ as compared with $MDRD_{186}$ and CKD-EPI formulae in the study patients (N = 607)

	eFGR in mL/min/1.73 m²	$MDRD_{175}$ n (%)						
		≥90	60–89	30–59	15–29	<15	Total	κ
CKD-EPI	**≥90**	267 (98.5)	79 (30.7)	-	-	-	346	
	60–89	4 (1.5)	178 (69.3)	15 (21.1)	-	-	197	
	30–59	-	-	56 (78.8)	-	-	56	**0.753**
	15–29	-	-	-	6 (100)	-	6	
	<15	-	-	-		2 (100)	2	
	Totals	**271**	**257**	**71**	**6**	**2**	**607**	
$MDRD_{186}$	**≥90**	271 (100)	66 (25.7)	-	-	-	337	
	60–89	-	191 (74.3)	22 (31)	-	-	213	
	30–59	-	-	49 (69)	-	-	49	**0.868**
	15–29	-	-	-	6 (100)	1 (50)	7	
	<15	-	-	-	-	1 (50)	2	
	Totals	**271**	**257**	**71**	**6**	**2**	**607**	

eGFR = estimated glomerular filtration rate; MDRD = modification of diet in renal disease; κ = kappa statistic; CKD-EPI = chronic kidney disease-epidemiology.

Table 6: Misclassification in CKD stages according to gender comparing different estimated glomerular filtration formulae in the study patients (N = 607)

Misclassifications of CKD stages	Age group in years	$MDRD_{186}$ and $MDRD_{175}$		$MDRD_{186}$ and CKD-EPI		$MDRD_{175}$ and CKD-EPI	
		Male	Female	Male	Female	Male	Female
Stage 1→2	**≤35**	4	-	-	-	-	-
	36–45	4	5	-	-	-	-
	46–55	10	13	-	-	-	-
	56–65	5	5	-	-	-	-
	>65	3	-	6	-	1	1
Stage 2→3	**46–55**	2	-	-	-	-	-
	56–65	4	3	-	-	-	-
	>65	5	8	3	5	-	1
Stage 2→1	**≤35**	-	-	1	-	5	-
	36–45	-	-	1	6	5	11
	46–55	-	-	4	5	14	18
	56–65	-	-	-	5	9	13
	>65	-	-	1	-	-	2
Stage 3→2	**46–55**	-	-	-	-	2	-
	56–65	-	-	-	-	4	-
	>65	-	-	-	-	2	3

CKD = chronic kidney disease; MDRD = modification of diet in renal disease; CKD-EPI = chronic kidney disease-epidemiology.

[Table 5]. Similarly, the $MDRD_{186}$ equation reclassified 66 (25.7%) and 22 (31.0%) patients as CKD stages 1 and 2 who had been in stages 2 and 3, respectively, according to the $MDRD_{175}$ equation.

A comparison of the data by age and gender between the three equations is shown in Table 6. The misclassification mostly involved CKD stages 1, 2 and 3. Apparently, the misclassification between $MDRD_{186}$ and $MDRD_{175}$ included an underestimation of GFR by $MDRD_{175}$ within all age groups, but particularly in those above 45 years of age. CKD-EPI overestimated GFR among those below 65 years of age and underestimated it in those over 65 as compared to $MDRD_{186}$. Similarly, CKD-EPI reclassified CKD stage 2 into stage 1 within all age groups as compared to $MDRD_{175}$. The misclassification of CKD stages using $MDRD_{186}$ and $MDRD_{175}$ involved more males than females among those above 45 years of age. However, the misclassification by CKD-EPI from $MDRD_{175}$ apparently involved more females in the older age groups.

Discussion

During the last decade, there has been increasing interest in the use of creatinine-based eGFR equations, with MDRD being considered the most valid formula.[6,15] In its original format, the $MDRD_{186}$ was recommended to be modified to the revised $MDRD_{175}$ for creatinine assays standardised to the IDMS reference method.[7–9] In the current study, the median eGFR (mL/min/1.73 m^2) was found to be 92.9 for $MDRD_{186}$, 87.4 for $MDRD_{175}$ and 93.7 for CKD-EPI, with the values being almost comparable for $MDRD_{186}$ and CKD-EPI. Only a few studies in the literature have compared the performance of $MDRD_{186}$ to various other GFR equations; most of them compared $MDRD_{175}$ with CKD-EPI. Chudleigh *et al*. compared the performance of $MDRD_{186}$ and $MDRD_{175}$ in their patient series based on the isotope gold-standard method.[17] The study reported a GFR of 114.9 ± 22.4 mL/min/1.73 m^2 for the isotope method, an eGFR of 94.7 ± 22.0 mL/min/1.73 m^2 for $MDRD_{175}$ and 89.9 ± 19.0 mL/min/1.73 m^2 for $MDRD_{186}$ (a CKD-EPI equation was not available at that time). Based on these results, Chudleigh *et al*. concluded that $MDRD_{175}$ is superior to $MDRD_{186}$ as its eGFR values were nearer to the isotope method than $MDRD_{186}$.[17] These data were surprising and questionable, and the numerical results for the two MDRD equations in their study could not be verified mathematically. Following the implementation of CKD-EPI, several studies showed an improved agreement of eGFR using CKD-EPI compared to using $MDRD_{175}$ based on isotope gold-standard methods.[12,13,18] However, these studies did not consider or include $MDRD_{186}$ in their comparison with CKD-EPI. Nevertheless, a comparative study involving European diabetic patients concluded a significant correlation between $MDRD_{186}$ (coefficient of determination [R^2] 0.818) and CKD-EPI (R^2 0.814) and the isotope gold-standard method.[28]

The difference in the prevalence of CKD using

the three equations can mostly be attributed to the redistribution in the prevalence of CKD stages 1, 2 and 3 as seen in the agreement analysis. The agreement between $MDRD_{186}$ and CKD-EPI is more efficient (κ 0.868) than the one between $MDRD_{186}$ and $MDRD_{175}$ (κ 0.753) or $MDRD_{175}$ and CKD-EPI (κ 0.730). A recent meta-analysis comparing the use of the CKD-EPI equation and the MDRD equation found that, when using the revised MDRD equation, 24.4% of participants were reclassified to a higher eGFR category by the CKD-EPI equation and the prevalence of CKD stages 3 to 5 (eGFR <60 mL/min/1.73 m^2) was reduced from 8.7% to 6.3%. The reclassification mainly involved CKD stage 3A to CKD stage 2.[25]

The distribution of gender and age within the misclassified cases was divided into two main groups: underestimated GFR and a subsequent reclassification of CKD stage, and overestimated GFR with a subsequent reclassification of CKD to a higher stage [Table 6]. When comparing $MDRD_{175}$ with $MDRD_{186}$, it was found that $MDRD_{175}$ clearly underestimated GFR in all age groups and predominantly affected males. In contrast, when comparing CKD-EPI and $MDRD_{186}$, the CKD-EPI predominantly underestimated GFR in those aged ≥65 years. The overestimation was much more pronounced when comparing CKD-EPI and $MDRD_{175}$. In a large cohort study in the UK, Carter *et al.* reported a median eGFR determined by CKD-EPI that was significantly higher than the median GFR determined by $MDRD_{175}$ (82 *versus* 76 mL/min/1.73 m2,[19] P <0.0001 with an overall mean bias of 5.0%) and a lower eGFR in those aged ≥70 years using CKD-EPI. However, Kilbride *et al.* reported that the CKD-EPI equation appears less biased and reasonably accurate in estimating GFR in both younger and older populations.[20] Earley *et al.* recently pointed out that neither MDRD nor CKD-EPI may be optimal for all ages and populations despite the potential promise of the CKD-EPI equation.[21] Moreover, the CKD-EPI equation performed as inadequately as the MDRD equation in T2DM individuals.[26,28] Patients' characteristics seem to account for the previously reported differences in the performance of CKD-EPI and MDRD equations.[27] With the good agreement between $MDRD_{186}$ and CKD-EPI, which is better than the agreement between $MDRD_{175}$ and CKD-EPI, it is worth considering the use of $MDRD_{186}$ whenever MDRD equations are implemented in practice, including in primary care—particularly bearing in mind the better agreement of CKD-EPI with radiolabelled methods. In addition, the CKD-EPI equation requires a complicated technical procedure in order to be incorporated into electronic healthcare systems.

The current cross-sectional study has some limitations. The study did not include a reference method for GFR measurements. However, comparison data were based on the status of MDRD and CKD-EPI equations in relation to the reference GFR methods in the cited publications. Also, the study was based mainly on single creatinine readings that might have affected the prevalence of CKD in the current diabetic population. Additionally, the population data were from PHCs; hence, many patients with CKD stages 4 and 5 might not have been included as these cases are usually referred to tertiary care institutions. Also, the population was mainly Arab-Asian, and since Arab ethnicity was not referred to in the MDRD or CKD-EPI equation, the factor in the equation was assumed to be 1.0. Further studies may be needed to validate these equations in the Arab-Asian population, taking into consideration that validated Japanese and Chinese MDRD equations have been reported in the literature.[22,23] For the Middle Eastern community, serum creatinine, age and gender have been utilised for estimating GFR using the aforementioned equations. No correction factor for ethnicity is considered which has led to the widespread acceptance of these equations by pathologists and clinicians.[7,15,24]

Conclusion

The performance of $MDRD_{186}$ and CKD-EPI in the calculation of GFR was, to a great extent, in agreement. Thus, calculated eGFR results using both equations were comparable. The revised $MDRD_{175}$ was found to underestimate GFR and thus increase the prevalence of CKD, particularly in stages 2 and 3, when compared with $MDRD_{186}$ and CKD-EPI. Taking into consideration that CKD-EPI-based eGFR has been reported to be near to isotopically measured GFR, the use of $MDRD_{186}$ may be recommended over $MDRD_{175}$. Also, before making any decision to change from $MDRD_{175}$ to CKD-EPI, the use of $MDRD_{186}$ should be considered.

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