

Formules d'estimation de la fonction rénale: Quand ça marche? Quand ça ne marche pas?

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Université de Liège
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7^{ème} Congrès
Maghrébin de
Néphrologie
15^{ème} Congrès
National de
Néphrologie
Marrakech
22 mars 2018



- 70 = septante

- 90 = nonante



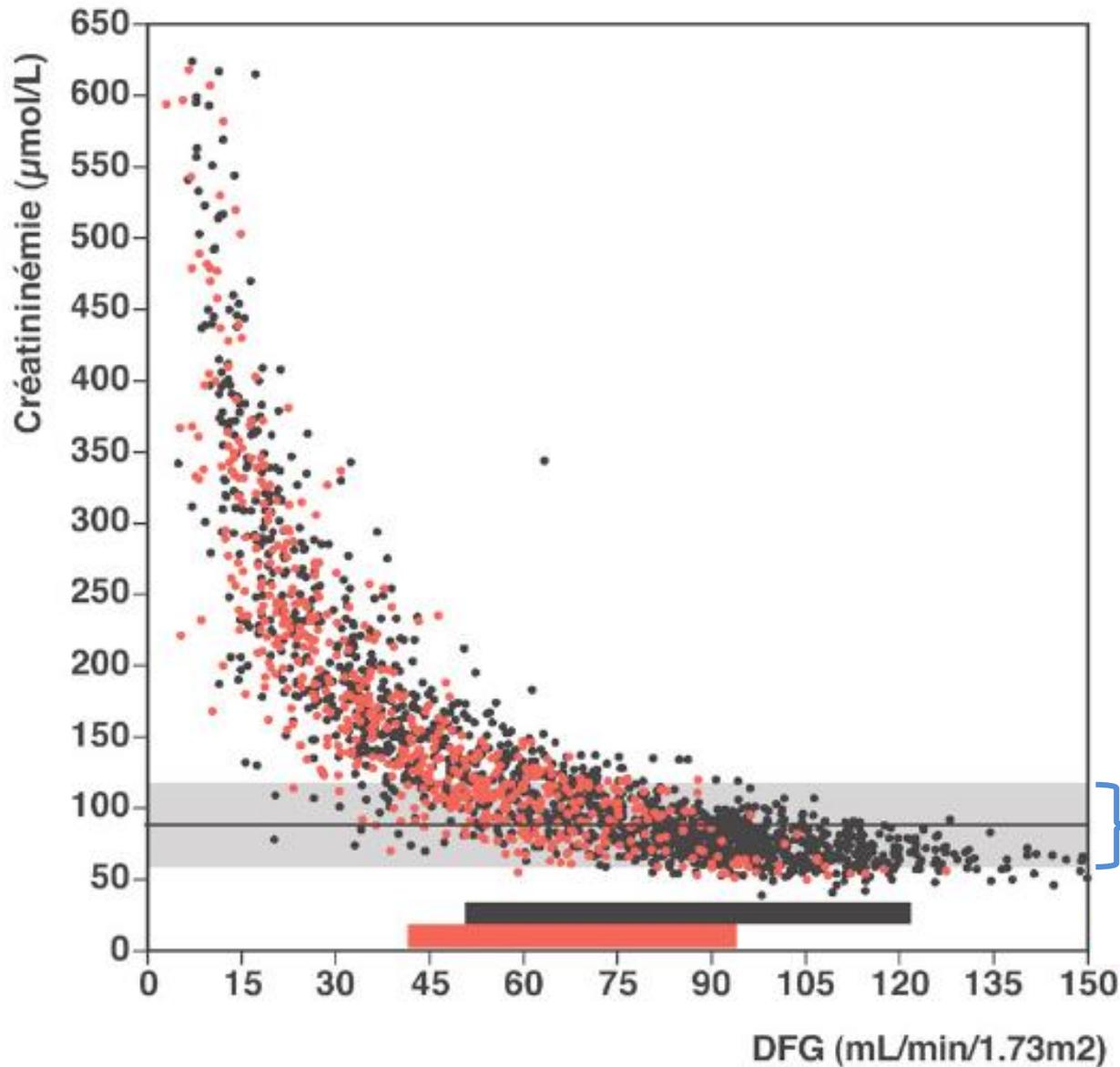
- Quelle formule? Quel biomarqueur?
- Populations spécifiques

Créatinine sérique

- Une des analyses les plus prescrites en Biologie Clinique
- ...mais le plus important est d'en connaître les limitations
- Limitations « analytiques »
- Limitations « physiologiques »
- Limitations « mathématiques »

Perrone RD, Clin Chem, 1992, 38, 1933

Delanaye P, Ann Biol Clin (Paris), 2010, 68, 531



Cohorte NephroTest
(France)

Quel DFG correspond à une
concentration de créatinine
mesurée à **0.9 mg/dL (80
 $\mu\text{mol/L}$)** ?

IC 95% pour sujets <65 ans
IC 95% pour sujets >65 ans

Valeurs normales
de créatinine

Avec la permission de Marc Froissart

Créatinine: « limitations mathématiques »

- Relation hyperbolique entre créatinine et DFG!!!

Pour un patient donné,

si la créatinine augmente de 0.6 à 1.2 mg/dl

=> diminution du DFG de 50%

si la créatinine augmente de 2.0 à 3.0 mg/dl

=> diminution du DFG de 25%

Mesure de la créatinine sérique

Limitations analytiques

- Méthodes de Jaffe: colorimétrique
- Méthodes enzymatiques
- Différentes méthodes mais aussi différents « assays »

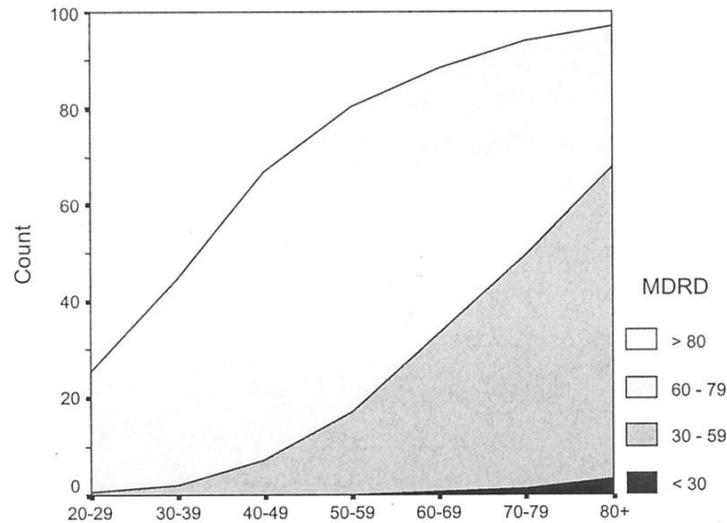
Perrone RD, Clin Chem, 1992, 38, 1933

Delanaye P, Ann Biol Clin (Paris), 2010, 68, 531

Mesure de la créatinine sérique

Limitations analytiques

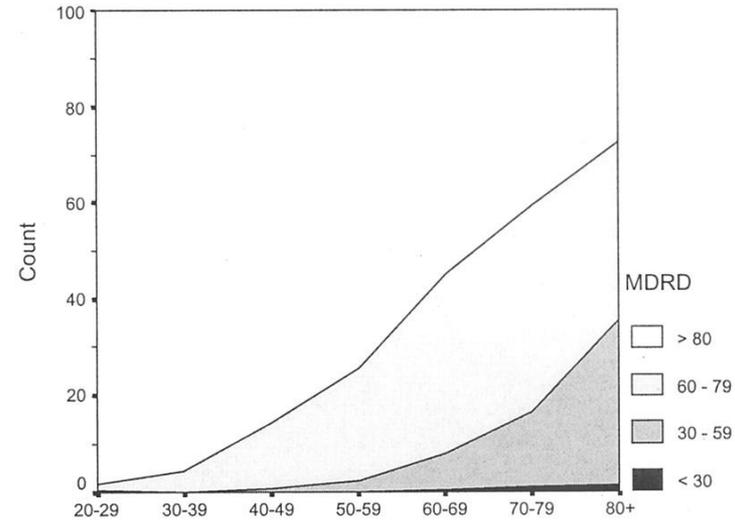
UNCALIBRATED



Age by decade

N	3037	2827	2138	1422	1670	1241	916	Total 13251
≥ 80	74.6%	55.2%	33.0%	19.5%	11.7%	6.1%	2.8%	41.8%
60-79	24.8%	42.7%	59.7%	63.3%	54.9%	44.2%	29.4%	45.4%
30-59	0.6%	2.0%	7.2%	17.2%	32.7%	48.5%	64.6%	12.5%
< 30	<0.1%	<0.1%	<0.1%	<0.1%	0.7%	1.2%	3.2%	0.3%

CALIBRATED



Age by decade

3037	2827	2138	1422	1670	1241	916	Total 13251
98.3%	95.7%	85.7%	74.4%	55.1%	40.7%	27.5%	82.1%
1.5%	4.2%	13.5%	23.3%	36.9%	42.7%	37.0%	14.5%
0.2%	<0.1%	0.8%	2.4%	7.6%	15.7%	34.3%	3.2%
<0.1%	<0.1%	<0.1%	<0.1%	0.5%	0.9%	1.2%	0.2%

Coresh, J. et al. *J Am Soc Nephrol* 2002;13:2811-2816

Limitations physiologiques

- Sécrétion tubulaire de créatinine

10 to 40%

Sécrétion augmente alors que DFG diminue

Non prédictible à l'échelon individuel

- Production extra-rénale

Perrone RD, Clin Chem, 1992, 38, 1933

Delanaye P, Ann Biol Clin (Paris), 2010, 68, 531

Limitations physiologiques

- Production (relativement) constante d'origine musculaire => la concentration de créatinine dépend de la masse musculaire, pas seulement du DFG
 - genre
 - âge
 - ethnicité
 - **Masse musculaire**

Creatinine: à la poubelle?

- Bon marché! (0.04€ /Jaffe)
- Bonne spécificité
- Bon CV analytique
- Préférence pour les méthodes enzymatiques

Clairance de créatinine

- N'est recommandée par aucun guidelines
- Sécrétion tubulaire
- Manque de précision:

erreurs dans la collecte

22 à 27% chez les patients « entraînés »

50 to 70 % pour les autres

importante variabilité intra-individuelle
de l'excrétion urinaire de créatinine

KDIGO, Kidney Int, 2012, 3

Perrone RD, Clin Chem, 1992, 38, 1933

Delanaye P, Ann Biol Clin (Paris), 2010, 68, 531

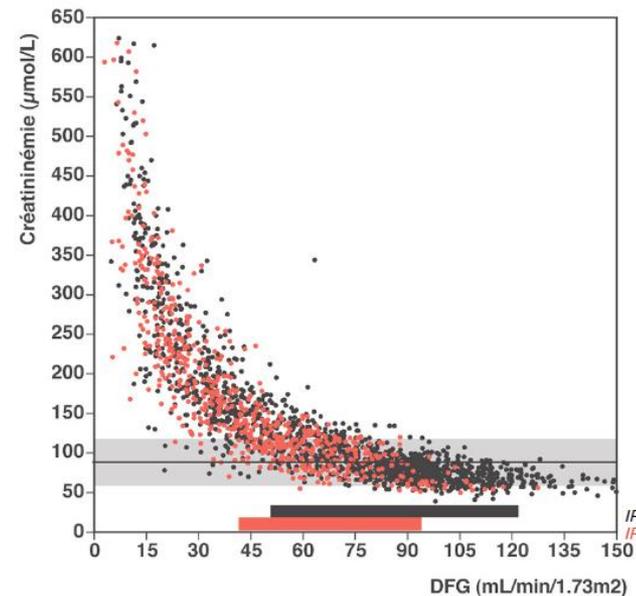
Clairance de créatinine

- Etude de Cockcroft
- Echantillon de départ n=236
- Echantillon de départ de 534: 2 clairances disponibles obtenues dans les services cliniques
- Exclusion de 56% (!) des sujets parce que :
 1. Variabilité de la créatinine sérique > 20%: n=29
 2. Excrétion de créatinine/24 h < 10 mg/d: n=31
 3. « Inadequate data »(?): n=65
 4. Variabilité de excrétion urinaire de créatinine > 20%:
n=173 (32%)

Equations basées sur la créatinine

But des équations:

- Conceptualiser la relation hyperbolique
- Adapter la créatinine pour l'âge, le genre, l'ethnicité
- Diminuer l'IC



Quelles équations?

- Cockcroft
- MDRD
- CKD-EPI
- Qqs autres

Table 1. MDRD study equations and Cockcroft equation commonly used for GFR estimation

Cockcroft and Gault

$$\text{GFR (ml/min)} = \frac{(140 - \text{age}) \times \text{weight (kg)}}{7.2 \times \text{SCr (mg/dl)}} \times 0.85 \text{ if woman}$$

4-Variable MDRD study equation (IDMS traceable)

$$\begin{aligned} \text{GFR (ml/min/1.73 m}^2\text{)} = \\ 175 \times \text{SCr (mg/dl)}^{-1.154} \times \text{age}^{-0.203} \times 0.742 \text{ (if woman)} \\ \times 1.21 \text{ for Black-American} \end{aligned}$$

Cockcroft DW, Nephron, 1976, 16, p31

Levey AS, Ann Intern Med, 1999, 130, p461

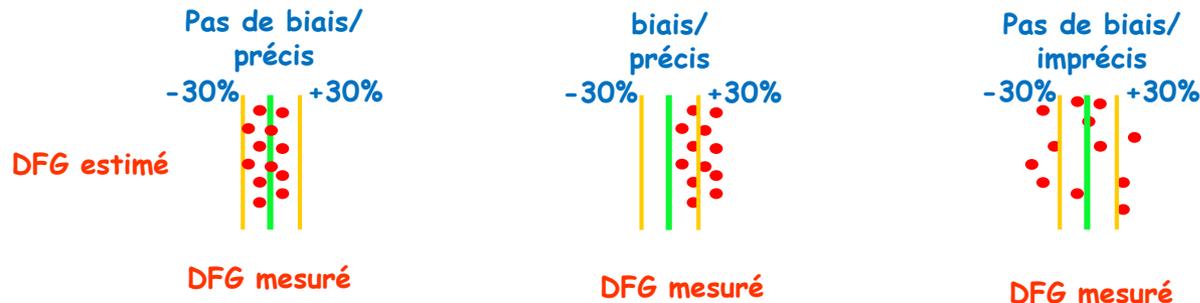
Cockcroft versus MDRD

	Cockcroft	MDRD
Population	Canada 1976	USA 1999
N	249	1628
DFG moyen	73	40
DFG de référence	Clairance de créatinine	Iothalamate
Assay	Jaffe	Jaffe calibré
% femmes	4	40
% noir	0 (?)	12
Age moyen	18-92	51
Poids moyen	72	79.6
Indexation pour BSA	Non	Oui
Validation interne	Non	Oui

Cockcroft DW, Nephron, 1976, 16, p31
Levey AS, Ann Intern Med, 1999, 130, p461

Statistiques

- Corrélation: une condition “*sine qua non*” mais insuffisante!
- Biais: différence moyenne entre 2 valeurs = erreur systématique
- Précision: SD autour de ce biais = erreur aléatoire
- Exactitude 30% = % du DFG estimée dans $\pm 30\%$ du DFG mesuré



Bland JM, Altman DG, Lancet, 1986, 8476, 307

Delanaye P, Nephrol Dial Transplant, 2013, 28, 1396

Predictive Performance of the Modification of Diet in Renal Disease and Cockcroft-Gault Equations for Estimating Renal Function

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‡Department of Nephrology, Georges Pompidou Hospital (AP-HP); §René Descartes Medical School, Paris V University; and ||Paris VI University, Paris, France

Recent recommendations emphasize the need to assess kidney function using creatinine-based predictive equations to optimize the care of patients with chronic kidney disease. The most widely used equations are the Cockcroft-Gault (CG) and the simplified Modification of Diet in Renal Disease (MDRD) formulas. However, they still need to be validated in large samples of subjects, including large non-U.S. cohorts. Renal clearance of ⁵¹Cr-EDTA was compared with GFR estimated using either the CG equation or the MDRD formula in a cohort of 2095 adult Europeans (863 female and 1232 male; median age, 53.2 yr; median measured GFR, 59.8 ml/min per 1.73 m²). When the entire study population was considered, the CG and MDRD equations showed very limited bias. They overestimated measured GFR by 1.94 ml/min per 1.73 m² and underestimated it by 0.99 ml/min per 1.73 m², respectively. However, analysis of subgroups defined by age, gender, body mass index, and GFR level showed that the biases of the two formulas could be much larger in selected populations. Furthermore, analysis of the SD of the mean difference between estimated and measured GFR showed that both formulas lacked precision; the CG formula was less precise than the MDRD one in most cases. In the whole study population, the SD was 15.1 and 13.5 ml/min per 1.73 m² for the CG and MDRD formulas, respectively. Finally, 29.2 and 32.4% of subjects were misclassified when the CG and MDRD formulas were used to categorize subjects according to the Kidney Disease Outcomes Quality Initiative chronic kidney disease classification, respectively.

J Am Soc Nephrol 16: 763–773, 2005. doi: 10.1681/ASN.2004070549

Table 3. Bias, precision, and accuracy of the MDRD and CG formulas^a

	N	Bland and Altman (ml/min per 1.73 m ²)		Accuracy within (% of Subjects)			CRMSE (ml/min per 1.73 m ²)
		Bias	Precision	15%	30%	50%	
MDRD formula							
high GFR ^b	1044	-3.3	17.2	61.3	92.4	98.8	17.5
low GFR ^c	1051	1.3	8.5	54.8	82.9	93.3	8.6
overall	2095	-1.0	13.7	58.0	87.2	96.0	13.8
CG formula							
high GFR ^b	1044	0.4	19.4	56.1	88.0	97.4	19.4
low GFR ^c	1051	3.5	9.7	41.2	69.0	85.2	10.3
overall	2095	1.9	15.4	48.7	78.5	91.3	15.5

^aResults obtained with these formulas were compared with GFR values obtained by measuring the renal clearance of ⁵¹Cr EDTA. Bias is defined as the mean difference between estimated and measured GFR. Precision is 1 SD of bias. Accuracy was assessed by determining the percentage of subjects who did not deviate >15, 30, and 50% from measured GFR and by calculating the combined root mean square error (CRMSE).

^bMeasured GFR ≥60 ml/min per 1.73 m².

^cMeasured GFR <60 ml/min per 1.73 m².

- 55
- Cr

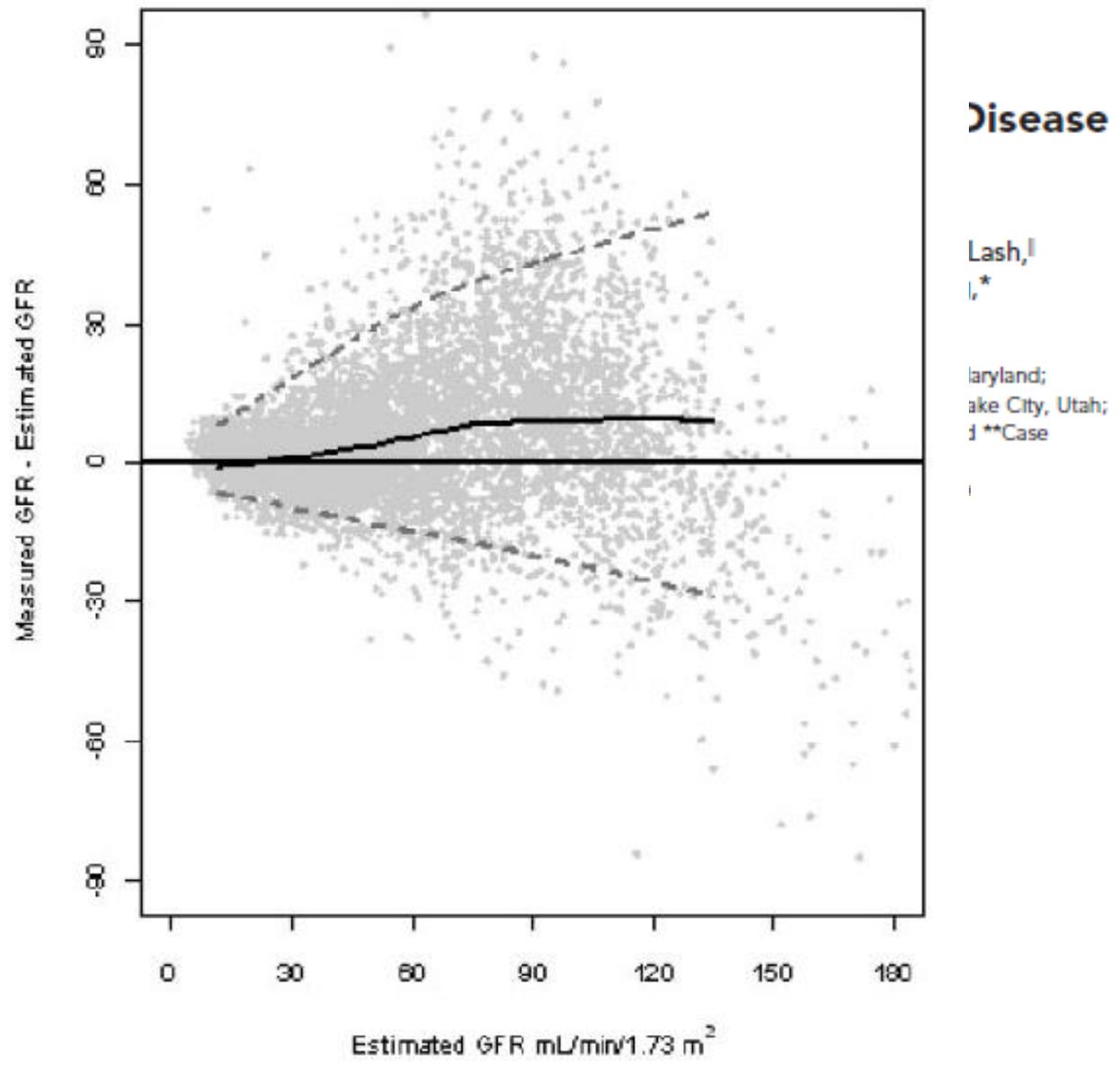


Figure 2. Difference of the MDRD Study equation by level of eGFR. Difference is calculated as (mGFR – eGFR). Solid horizontal

MDRD: les forces

- Bonne performance surtout aux stades 3-4 MRC
- Exactitude attendue: 80-85%
- Mieux que Cockcroft en termes de précision

MDRD: les limitations

- MDRD biais absolu plus élevé et précision moindre dans les valeurs hautes de DFG
- Proportion non-négligeable de sujets au stade 2 qui seront faussement classifié au stade 3

Equation CKD-EPI

A New Equation to Estimate Glomerular Filtration Rate

Andrew S. Levey, MD; Lesley A. Stevens, MD, MS; Christopher H. Schmid, PhD; Yaping (Lucy) Zhang, MS; Alejandro F. Castro III, MPH; Harold I. Feldman, MD, MSCE; John W. Kusek, PhD; Paul Eggers, PhD; Frederick Van Lente, PhD; Tom Greene, PhD; and Josef Coresh, MD, PhD, MHS, for the CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration)*

Ann Intern Med. 2009;150:604-612.

Table 2. The CKD-EPI Equation for Estimating GFR on the Natural Scale*

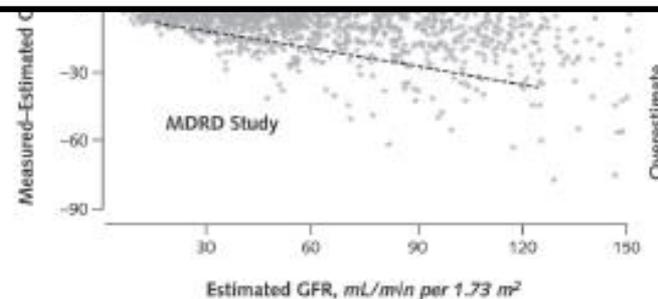
Race and Sex	Serum Creatinine Level, $\mu\text{mol/L}$ (mg/dL)	Equation
Black		
Female	≤ 62 (≤ 0.7)	$\text{GFR} = 166 \times (\text{Scr}/0.7)^{-0.329} \times (0.993)^{\text{Age}}$
	> 62 (> 0.7)	$\text{GFR} = 166 \times (\text{Scr}/0.7)^{-1.209} \times (0.993)^{\text{Age}}$
Male	≤ 80 (≤ 0.9)	$\text{GFR} = 163 \times (\text{Scr}/0.9)^{-0.411} \times (0.993)^{\text{Age}}$
	> 80 (> 0.9)	$\text{GFR} = 163 \times (\text{Scr}/0.9)^{-1.209} \times (0.993)^{\text{Age}}$
White or other		
Female	≤ 62 (≤ 0.7)	$\text{GFR} = 144 \times (\text{Scr}/0.7)^{-0.329} \times (0.993)^{\text{Age}}$
	> 62 (> 0.7)	$\text{GFR} = 144 \times (\text{Scr}/0.7)^{-1.209} \times (0.993)^{\text{Age}}$
Male	≤ 80 (≤ 0.9)	$\text{GFR} = 141 \times (\text{Scr}/0.9)^{-0.411} \times (0.993)^{\text{Age}}$
	> 80 (> 0.9)	$\text{GFR} = 141 \times (\text{Scr}/0.9)^{-1.209} \times (0.993)^{\text{Age}}$

- CKD-EPI
- “Development dataset”: n=5504
- “Internal validation”: n=2750
- “External validation”: n=3896
- Créatinine calibrée
- DFG médian = 68 mL/min/1.73 m²

Figure. Performance of the CKD-EPI and MDRD Study equations in estimating measured GFR in the external validation data set.

Table 3. Comparison of the CKD-EPI and MDRD Study Equations in Estimating Measured GFR in the Validation Data Set*

Variable and Equation	All Patients	Patients With Estimated GFR <60 mL/min per 1.73 m ²	Patients With Estimated GFR ≥60 mL/min per 1.73 m ²
Median difference (95% CI), mL/min per 1.73 m²†			
CKD-EPI	2.5 (2.1–2.9)	2.1 (1.7–2.4)	3.5 (2.6–4.5)
MDRD Study	5.5 (5.0–5.9)	3.4 (2.9–4.0)	10.6 (9.8–11.3)
Interquartile range for differences (95% CI), mL/min per 1.73 m²‡			
CKD-EPI	16.6 (15.9–17.3)	11.3 (10.7–12.1)	24.2 (22.8–25.3)
MDRD Study	18.3 (17.4–19.3)	12.9 (12.0–13.6)	25.7 (24.4–27.1)
P₂₀ (95% CI), %§			
CKD-EPI	84.1 (83.0–85.3)	79.9 (78.1–81.7)	88.3 (86.9–89.7)
MDRD Study	80.6 (79.5–82.0)	77.2 (75.5–79.0)	84.7 (83.0–86.3)
Root mean square error (95% CI)			
CKD-EPI	0.250 (0.241–0.259)	0.284 (0.270–0.298)	0.213 (0.203–0.223)
MDRD Study	0.274 (0.265–0.283)	0.294 (0.280–0.308)	0.248 (0.238–0.258)



Discussion:

MDRD or CKD-EPI ?

- Prévalence plus basse de la MDRD dans les études épidémiologiques
- Meilleure prédiction CV => meilleures à l'échelle population
- Meilleur biais pour les DFG >60 (90?) ml/min/1.73m² mais précision pas meilleure => réellement meilleur à l'échelle individuelle?

Systematic Review the Modification Epidemiology Co

McFadden EC¹, Hirst JA¹,
DS^{4,2,5}

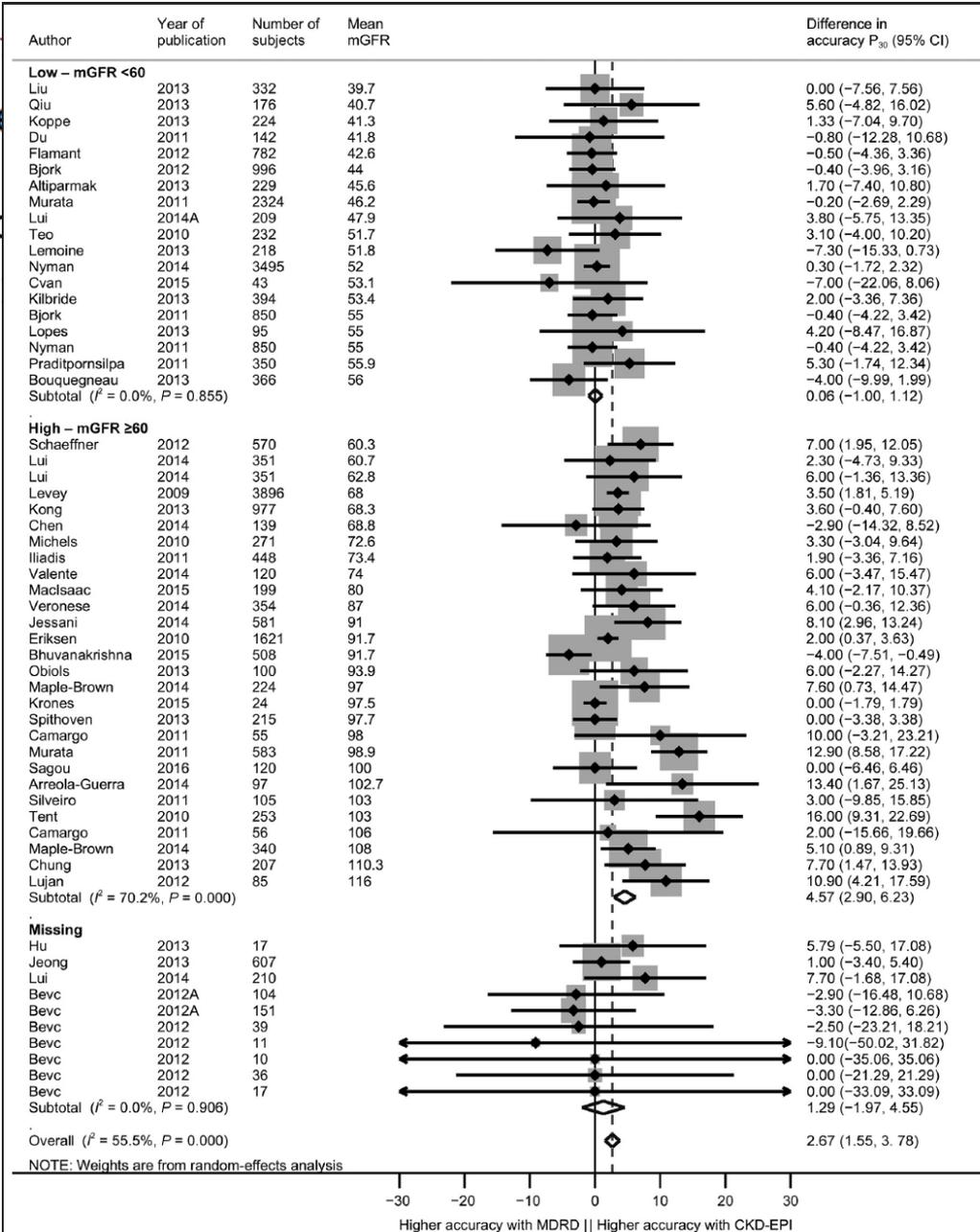


Fig. 4. Difference in mean accuracy from CKD-EPI and mean accuracy from MDRD, and pooled estimate (diamond) stratified into subgroups of high and low mGFR using random-effects metaanalysis. P₃₀, proportion of eGFR results within 30% of mGFR result. Horizontal bars and diamond width denote 95% CIs, and box sizes indicate relative weight in the analysis.

Accuracy of
eGFR
estimations.
Lasserson

Le prix à payer?

Relative Performance of the MDRD and CKD-EPI Equations for Estimating Glomerular Filtration Rate among Patients with Varied Clinical Presentations

Kazunori Murata,* Nikola A. Baumann,* Amy K. Saenger,* Timothy S. Larson,** Andrew D. Rule,** and John C. Lieske**

Summary

Background The Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation was developed using both CKD and non-CKD patients to potentially replace the Modification of Diet in Renal Disease (MDRD) equation that was derived with only CKD patients. The objective of our study was to compare the accuracy of the MDRD and CKD-EPI equations for estimating GFR in a large group of patients having GFR measurements for diverse clinical indications.

Design, setting, participants, and measurements A cross-sectional study was conducted of patients who underwent renal function assessment for clinical purposes by simultaneous measurements of serum creatinine and estimation of GFR using the MDRD and CKD-EPI equations and renal clearance of iothalamate ($n = 5238$).

Results Bias compared with measured GFR (mGFR) varied for each equation depending on clinical presentation. The CKD-EPI equation demonstrated less bias than the MDRD equation in potential kidney donors (-8% versus -18%) and postnephrectomy donors (-7% versus -15%). However, the CKD-EPI equation was slightly more biased than the MDRD equation in native CKD patients (6% versus 3%), kidney recipients (8% versus 1%), and other organ recipients (9% versus 3%). Among potential kidney donors, the CKD-EPI equation had higher specificity than the MDRD equation for detecting an mGFR <60 ml/min per 1.73 m² (98% versus 94%) but lower sensitivity (50% versus 70%).

Conclusions Clinical presentation influences the estimation of GFR from serum creatinine, and neither the CKD-EPI nor MDRD equation account for this. Use of the CKD-EPI equation misclassifies fewer low-risk patients as having reduced mGFR, although it is also less sensitive for detecting mGFR below specific threshold values used to define CKD stages.

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Le prix à payer? (provocation!)

- Quel serait votre choix?

Mieux estimer le DFG d'un sujet avec une DFG mesuré entre 90 et 120 mL/min/1.73 m²?

Mieux estimer le DFG d'un patient avec un DFG mesuré entre 30 et 60 mL/min/1.73 m²?



MDRD (et CKD-EPI): facteurs ethniques???

- Facteur asiatique: Chinois: 1.233 Japonnais: 0.808
Comment expliquer une telle différence?

Delanaye P, Kidney Int, 2011 80, 439

- Facteur Afro-Américain factor: 1.21
Trop élevé pour la population saine

Delanaye P, Clin J Am Soc, 2011, 6, 906

Facteur(s) ethnique(s) CKD/EPI - MDRD

RESEARCH LETTER

Performance of GFR Estimating Equations in African Europeans: Basis for a Lower Race-Ethnicity Factor Than in African Americans

Flamant M et al Am J Kidney Dis, 2013, 62, p179

NON

Néphrologie & Thérapeutique 12 (2016) 454-459

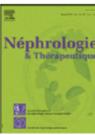


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RESEARCH ARTICLE

Performance of glomerular filtration rate estimation equations in Congolese healthy adults: The inopportunity of the ethnic correction

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Article original

Inadéquation du facteur ethnique pour l'estimation du débit de filtration glomérulaire en population générale noire-africaine : résultats en Côte d'Ivoire

Inadequacy of the African-American ethnic factor to estimate glomerular filtration rate in an African general population: Results from Côte d'Ivoire

Éric Sagou Yayo^a, Mireille Aye^a, Jean-Louis Konan^a, Arlette Emième^b, Marie-Laure Attoungbre^a, Appolinaire Gnionsahé^c, Étienne Cavalier^d, Dagui Monnet^a, Pierre Delanaye^{e,*}



Yayo ES, *Nephrol Ther*, 2016, 12, 454
Flamant M, *Am J Kidney Dis*, 2013, 62, 179
Bukabau JB, *Plos One*, 2018, 13, e0193384



MDRD – CKD-EPI: What else?

- Equation Bis
- Equation Lund-Malmö
- Equation FAS
- Autre biomarqueurs: cystatine C

Schaeffner, Ann intern Med, 2012, 157, 471

Bjork, Scand J Urol Nephrol, 2012, 46, 212

Pottel H, Nephrol Dial Transplant, 2016

Seronie-Vivien, CCLM, 2008

Two Novel Equations to Estimate Kidney Function in Persons Aged 70 Years or Older

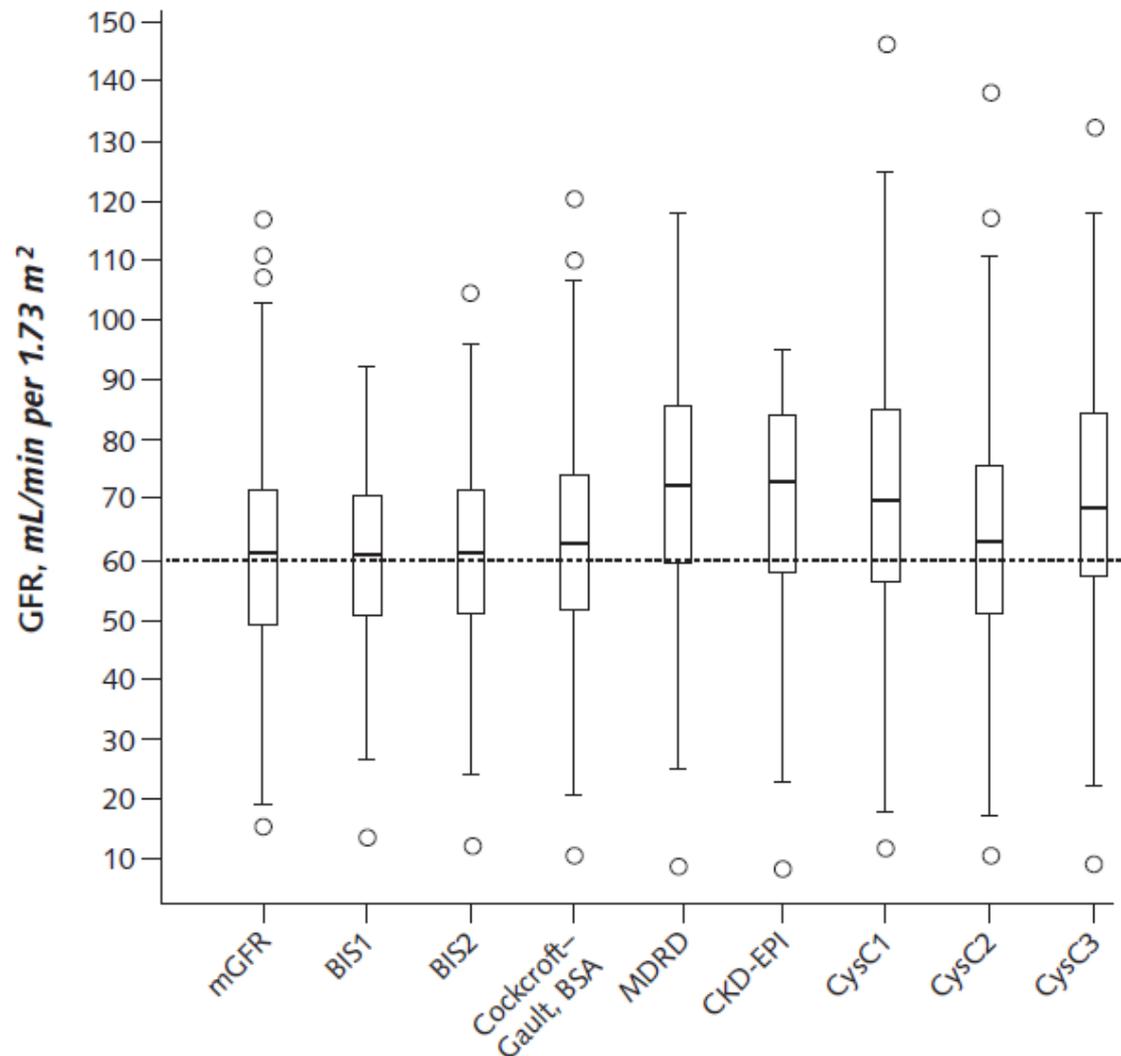
Elke S. Schaeffner, MD, MS*; Natalie Ebert, MD, MPH*; Pierre Delanaye, MD, PhD; Ulrich Frei, MD; Jens Gaedeke, MD; Olga Jakob; Martin K. Kuhlmann, MD; Mirjam Schuchardt, PhD; Markus Tölle, MD; Reinhard Ziebig, PhD; Markus van der Giet, MD; and Peter Martus, PhD

BIS1:

$$3736 \times \text{creatinine}^{-0.87} \times \text{age}^{-0.95} \times 0.82 \text{ (if female)}$$

- n=610, iohexol, créatinine enzymatiques calibrée
- DFG moyen = 52 mL/min/1,73 m²

Figure 1. Comparison of mGFR with eGFR equations in the validation sample.



Boxes indicate medians (*line inside box*), quartiles (*upper and lower margins of box*). Antennae are defined by the rule upper–lower box margin $\pm 1.5 \times$ interquartile range. Circles indicate outliers.

Ulf Nyman*, Anders Grubb, Anders Larsson, Lars-Olof Hansson, Mats Flodin, Gunnar Nordin, Veronica Lindström and Jonas Björk

The revised Lund-Malmö GFR estimating equation outperforms MDRD and CKD-EPI across GFR, age and BMI intervals in a large Swedish population

Clin Chem Lab Med 2014, 52(6), 815-824

Revised Lund-Malmö Study equation (LM Revised) [34]

$$e^{X-0.0158 \times \text{Age} + 0.438 \times \ln(\text{Age})}$$

Female pCr < 150 µmol/L: $X = 2.50 + 0.0121 \times (150 - \text{pCr})$

Female pCr ≥ 150 µmol/L: $X = 2.50 - 0.926 \times \ln(\text{pCr}/150)$

Male pCr < 180 µmol/L: $X = 2.56 + 0.00968 \times (180 - \text{pCr})$

Male pCr ≥ 180 µmol/L: $X = 2.56 - 0.926 \times \ln(\text{pCr}/180)$

- Lund-Malmö
- n=3495 (chez 2847 sujets), iohexol, créatinine calibrée
- DFG moyen = 60 mL/min/1,73 m²

An estimated glomerular filtration rate equation for the full age spectrum

Hans Pottel¹, Liesbeth Hoste¹, Laurence Dubourg², Natalie Ebert³, Elke Schaeffner³, Bjørn Odvar Eriksen⁴, Toralf Melsom⁴, Edmund J. Lamb⁵, Andrew D. Rule⁶, Stephen T. Turner⁶, Richard J. Glasscock⁷, Vandr ea De Souza⁸, Luciano Selistre⁹, Christophe Mariat¹⁰, Frank Martens¹¹ and Pierre Delanaye¹²

Example 1: A healthy 18-year-old male with a body height (L) of 180 cm and SCr of 0.90 mg/dL:

Paediatric equation (Schwartz): $eGFR = 0.413 \times L/SCr = 0.413 \times 180/0.90 = 83 \text{ mL/min/1.73 m}^2$.

Adult equation (CKD-EPI): $eGFR = 141 \times (0.90/0.90)^{-1.209} \times 0.993^{18} = 124 \text{ mL/min/1.73 m}^2$. **+50%**

Table 1. Q-values [=median serum creatinine in $\mu\text{mol/L}$ (mg/dL)] for the FAS equation, according to age or height (from refs [4, 5, 10])

Age, years	Height ^a , cm	Q ^b , $\mu\text{mol/L}$ (mg/dL)
Boys and girls		
1	75.0	23 (0.26)
2	87.0	26 (0.29)
3	95.5	27 (0.31)
4	102.5	30 (0.34)
5	110.0	34 (0.38)
6	116.7	36 (0.41)
7	123.5	39 (0.44)
8	129.5	41 (0.46)
9	135.0	43 (0.49)
10	140.0	45 (0.51)
11	146.0	47 (0.53)
12	152.5	50 (0.57)
13	159.0	52 (0.59)
14	165.0	54 (0.61)
Male adolescents		
15	172.0	64 (0.72)
16	176.0	69 (0.78)
17	178.0	72 (0.82)
18	179.0	75 (0.85)
19	180.0	78 (0.88)
Male adults		
≥20	≥181.5	80 (0.90)
Female adolescents		
15	164.5	57 (0.64)
16	166.0	59 (0.67)
17	166.5	61 (0.69)
18	167.0	61 (0.69)
19	167.5	62 (0.70)
Female adults		
≥20	≥168.0	62 (0.70)

^aHeight is the median height of a child or adolescent at the specified age (Belgian growth curves).

Table 3. Prediction performance results of different eGFR equations on the pooled databases according to age group and measured GFR categories (mGFR below or above 60 mL/min/1.73 m²)

Pooled data	eGFR equivalent	RMSE (95% CI)	Constant bias (95% CI)	Proportional bias (95% CI)	P10, % (95% CI)	P30, % (95% CI)
Children and adolescents <18 years						
All (n = 735)	FAS	20.1 (18.5, 21.6)	-1.7 (-3.1, -0.2) ^{*,†}	1.01 (0.99, 1.03) ^{*,†}	40.1 (36.6, 43.7)	87.5 (85.1, 89.9) [*]
mGFR = 94.5	FAS-height	19.8 (18.1, 21.4)	-2.7 (-4.1, -1.3) ^{*,‡}	1.00 (0.98, 1.01) ^{*,‡}	41.9 (38.3, 45.5)	88.8 (86.6, 91.1) [†]
	Schwartz	21.7 (19.5, 23.7)	6.0 (4.5, 7.5) ^{†,‡}	1.09 (1.07, 1.11) ^{†,‡}	40.1 (36.6, 43.7)	83.8 (81.1, 86.5) ^{*,†}
mGFR < 60 (n = 99)	FAS	14.6 (8.5, 18.9)	6.2 (3.6, 8.9) ^{*,†}	1.15 (1.09, 1.21) ^{*,†}	34.3 (24.8, 43.9)	75.8 (67.2, 84.3)
	FAS-height	13.5 (4.2, 18.6)	4.7 (2.2, 7.2) ^{*,‡}	1.12 (1.06, 1.17) ^{*,‡}	39.4 (25.6, 49.2)	77.8 (69.4, 86.1) [*]
mGFR ≥ 60 (n = 636)	Schwartz	16.7 (8.2, 22.1)	9.4 (6.7, 12.2) ^{†,‡}	1.22 (1.16, 1.28) ^{†,‡}	31.3 (22.0, 40.6)	70.7 (61.6, 79.8) [*]
	FAS	20.8 (19.1, 22.4)	-2.9 (-4.5, -1.3) ^{*,†}	0.99 (0.97, 1.00) ^{*,†}	41.0 (37.2, 44.9)	89.3 (86.9, 91.7) [*]
mGFR = 102.2	FAS-height	20.6 (18.9, 22.3)	-3.8 (-5.4, -2.3) ^{*,‡}	0.98 (0.96, 0.99) ^{*,‡}	42.3 (38.4, 46.1)	90.6 (88.3, 92.8) [†]
	Schwartz	22.4 (20.0, 24.5)	5.4 (3.7, 7.1) ^{†,‡}	1.07 (1.05, 1.09) ^{†,‡}	41.5 (37.7, 45.3)	85.8 (83.1, 88.6) ^{*,†}
Adults 18–70 years						
All (n = 4371)	FAS	17.2 (16.6, 17.8)	5.0 (4.5, 5.5) [*]	1.12 (1.11, 1.12) [*]	40.4 (38.9, 41.9) [*]	81.6 (80.4, 82.7)
mGFR = 78.6	CKD-EPI	16.4 (15.8, 16.9)	6.3 (5.9, 6.8) [*]	1.13 (1.12, 1.14) [*]	42.5 (41.1, 44.0) [*]	81.9 (80.7, 83.0)
mGFR < 60 (n = 1089)	FAS	19.0 (17.7, 20.2)	13.4 (12.6, 14.2) [*]	1.35 (1.33, 1.37) [*]	19.1 (16.8, 21.4) [*]	52.2 (49.3, 55.2) [*]
	CKD-EPI	19.2 (18.1, 20.3)	12.7 (11.8, 13.5) [*]	1.31 (1.29, 1.34) [*]	21.9 (19.4, 24.3) [*]	55.2 (52.2, 58.1) [*]
mGFR ≥ 60 (n = 3282)	FAS	16.6 (15.9, 17.2) [*]	2.2 (1.6, 2.7) [*]	1.04 (1.03, 1.04) [*]	47.5 (45.8, 49.2) [*]	91.3 (90.3, 92.3)
	CKD-EPI	15.3 (14.7, 15.8) [*]	4.2 (3.7, 4.7) [*]	1.07 (1.06, 1.07) [*]	49.4 (47.7, 51.1) [*]	90.7 (89.7, 91.7)
Older adults ≥70 years						
All (n = 1764)	FAS	11.2 (10.7, 11.7) [*]	-1.1 (-1.6, -0.6) [*]	1.02 (1.01, 1.03) [*]	39.7 (37.5, 42.0) [*]	86.1 (84.4, 87.7) [*]
	mGFR = 55.6	CKD-EPI	12.9 (12.4, 13.4) [*]	5.6 (5.1, 6.2) [*]	1.13 (1.12, 1.15) [*]	35.0 (32.8, 37.3) [*]
mGFR < 60 (n = 986)	BIS1 ^a	12.0 (11.4, 12.6)	-1.2 (-1.9, -0.6)	1.05 (1.03, 1.07)	34.7 (32.0, 37.4)	81.8 (79.7, 84.0)
	FAS	9.5 (8.8, 10.1) [*]	2.2 (1.6, 2.7) [*]	1.09 (1.07, 1.11) [*]	36.6 (33.6, 39.6) [*]	81.0 (78.6, 83.5) [*]
mGFR = 40.7	CKD-EPI	13.1 (12.3, 13.8) [*]	6.9 (6.2, 7.6) [*]	1.19 (1.17, 1.21) [*]	29.5 (26.7, 32.4) [*]	67.7 (64.8, 70.7) [*]
	BIS1 ^a	9.7 (9.0, 10.3)	3.7 (3.0, 4.4)	1.16 (1.13, 1.18)	35.3 (31.8, 38.8)	75.4 (72.2, 78.5)
mGFR ≥ 60 (n = 778)	FAS	13.1 (12.3, 13.8)	-5.2 (-6.1, -4.4) [*]	0.94 (0.93, 0.95) [*]	43.7 (40.2, 47.2)	92.4 (90.6, 94.3)
	CKD-EPI	12.7 (12.1, 13.3)	4.1 (3.2, 4.9) [*]	1.07 (1.06, 1.08) [*]	42.0 (38.6, 45.5)	90.1 (88.0, 92.2)
mGFR = 74.4	BIS1 ^a	14.8 (13.7, 15.7)	-8.6 (-9.7, -7.5)	0.90 (0.88, 0.91)	33.9 (29.6, 38.1)	91.5 (89.0, 94.0)

The same symbols (*, †, ‡) within each subgroup and column indicate significant differences (paired *t*-test for constant and proportional bias, McNemar's test for P10 and P30 = % of subjects with an eGFR value within 10% and 30% of measured GFR).

^aFor the BIS1 performance results, the data (n = 570) from the BIS1 study were not included (therefore, no comparisons with FAS and CKD-EPI were made).

Cystatin C

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Estimating Glomerular Filtration Rate from Serum Creatinine and Cystatin C

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John H. Eckfeldt, M.D., Ph.D., Harold I. Feldman, M.D., Tom Greene, Ph.D.,
John W. Kusek, Ph.D., Jane Manzi, Ph.D., Frederick Van Lente, Ph.D.,
Yaping Lucy Zhang, M.S., Josef Coresh, M.D., Ph.D., and Andrew S. Levey, M.D.,
for the CKD-EPI Investigators*

Table 1. Characteristics of Study Participants, According to Data Set.*

Characteristic	Development and Internal Validation (N = 5352)	External Validation (N = 1119)	P Value
Age — yr	47±15	50±17	<0.001
Age group — no. (%)			
<40 yr	2008 (38)	357 (32)	<0.001
40–65 yr	2625 (49)	530 (47)	
>65 yr	719 (13)	232 (21)	
Male sex — no. (%)	3107 (58)	663 (59)	0.46
Black race — no. (%)†	2123 (40)	30 (3)	<0.001
Diabetes — no. (%)	1726 (32)	594 (53)	<0.001
Body-mass index‡			
Mean	28±6	25±4	<0.001
<20 — no. (%)	214 (4)	81 (7)	<0.001
20–24 — no. (%)	1585 (30)	503 (45)	
25–30 — no. (%)	1881 (35)	386 (35)	
>30 — no. (%)	1671 (31)	149 (13)	
Mean weight — kg	83±20	74±15	<0.001
Mean height — cm	171±10	170±9	0.017
Mean body-surface area — m ²	1.94±0.24	1.85±0.21	<0.001
Mean serum cystatin C — ml/liter	1.4±0.7	1.5±0.8	0.01
Mean serum creatinine — mg/dl§	1.6±0.9	1.6±1.1	0.15
Mean measured GFR — ml/min/1.73 m ² of body-surface area	68±39	70±41	0.13
Measured GFR — no. (%)			
<15 ml/min/1.73 m ²	160 (3)	51 (5)	<0.001
15–29 ml/min/1.73 m ²	785 (15)	166 (15)	
30–59 ml/min/1.73 m ²	1765 (33)	316 (28)	
60–89 ml/min/1.73 m ²	1105 (21)	215 (19)	
90–119 ml/min/1.73 m ²	862 (16)	199 (18)	
>120 ml/min/1.73 m ²	675 (13)	172 (15)	

Table 2. Creatinine Equation (CKD-EPI 2009), Cystatin C Equation (CKD-EPI 2012), and Creatinine–Cystatin C Equation (CKD-EPI 2012) for Estimating GFR, Expressed for Specified Sex, Serum Creatinine Level, and Serum Cystatin C Level.*

Basis of Equation and Sex	Serum Creatinine†	Serum Cystatin C	Equation for Estimating GFR
	mg/dl	mg/liter	
CKD-EPI creatinine equation‡			
Female	≤0.7		$144 \times (\text{Scr}/0.7)^{-0.329} \times 0.993^{\text{Age}} [\times 1.159 \text{ if black}]$
Female	>0.7		$144 \times (\text{Scr}/0.7)^{-1.209} \times 0.993^{\text{Age}} [\times 1.159 \text{ if black}]$
Male	≤0.9		$141 \times (\text{Scr}/0.9)^{-0.411} \times 0.993^{\text{Age}} [\times 1.159 \text{ if black}]$
Male	>0.9		$141 \times (\text{Scr}/0.9)^{-1.209} \times 0.993^{\text{Age}} [\times 1.159 \text{ if black}]$
CKD-EPI cystatin C equation§			
Female or male		≤0.8	$133 \times (\text{Scys}/0.8)^{-0.499} \times 0.996^{\text{Age}} [\times 0.932 \text{ if female}]$
Female or male		>0.8	$133 \times (\text{Scys}/0.8)^{-1.328} \times 0.996^{\text{Age}} [\times 0.932 \text{ if female}]$
CKD-EPI creatinine–cystatin C equation¶			
Female	≤0.7	≤0.8	$130 \times (\text{Scr}/0.7)^{-0.248} \times (\text{Scys}/0.8)^{-0.375} \times 0.995^{\text{Age}} [\times 1.08 \text{ if black}]$
		>0.8	$130 \times (\text{Scr}/0.7)^{-0.248} \times (\text{Scys}/0.8)^{-0.711} \times 0.995^{\text{Age}} [\times 1.08 \text{ if black}]$
Female	>0.7	≤0.8	$130 \times (\text{Scr}/0.7)^{-0.601} \times (\text{Scys}/0.8)^{-0.375} \times 0.995^{\text{Age}} [\times 1.08 \text{ if black}]$
		>0.8	$130 \times (\text{Scr}/0.7)^{-0.601} \times (\text{Scys}/0.8)^{-0.711} \times 0.995^{\text{Age}} [\times 1.08 \text{ if black}]$
Male	≤0.9	≤0.8	$135 \times (\text{Scr}/0.9)^{-0.207} \times (\text{Scys}/0.8)^{-0.375} \times 0.995^{\text{Age}} [\times 1.08 \text{ if black}]$
		>0.8	$135 \times (\text{Scr}/0.9)^{-0.207} \times (\text{Scys}/0.8)^{-0.711} \times 0.995^{\text{Age}} [\times 1.08 \text{ if black}]$
Male	>0.9	≤0.8	$135 \times (\text{Scr}/0.9)^{-0.601} \times (\text{Scys}/0.8)^{-0.375} \times 0.995^{\text{Age}} [\times 1.08 \text{ if black}]$
		>0.8	$135 \times (\text{Scr}/0.9)^{-0.601} \times (\text{Scys}/0.8)^{-0.711} \times 0.995^{\text{Age}} [\times 1.08 \text{ if black}]$

Table 3. Use of the CKD-EPI Creatinine Equation (2009), CKD-EPI Cystatin C Equation (2012), and CKD-EPI Creatinine–Cystatin C Equations (2012) in the External-Validation Data Set Comprising 1119 Participants.*

Variable	Estimated GFR			
	Overall	<60	60–89	≥90
	<i>ml/min/1.73 m² of body-surface area</i>			
Bias — median difference (95% CI)				
Creatinine equation	3.7 (2.8 to 4.6)	1.8 (1.1 to 2.5)	6.6 (3.5 to 9.2)	11.1 (8.0 to 12.5)
Cystatin C equation	3.4 (2.3 to 4.4)	0.4 (–0.5 to 1.4)	6.0 (4.6 to 8.5)	8.5 (6.5 to 11.2)
Creatinine–cystatin C equation	3.9 (3.2 to 4.5)	1.3 (0.5 to 1.8)	6.9 (5.0 to 8.9)	10.6 (9.5 to 12.7)
Average of creatinine and cystatin C†	3.5 (2.8 to 4.1)	0.4 (–0.3 to 0.8)	6.5 (4.6 to 8.4)	11.9 (9.9 to 13.9)
Precision — IQR of the difference (95% CI)				
Creatinine equation	15.4 (14.3 to 16.5)	10.0 (8.9 to 11.0)	19.6 (17.3 to 23.2)	25.0 (21.6 to 28.1)
Cystatin C equation	16.4 (14.8 to 17.8)	11.0 (10.0 to 12.4)	19.6 (16.1 to 23.1)	22.6 (18.8 to 26.3)
Creatinine–cystatin C equation	13.4 (12.3 to 14.5)	8.1 (7.3 to 9.1)	15.9 (13.9 to 18.1)	18.8 (16.8 to 22.5)
Average of creatinine and cystatin C equations†	13.9 (12.9 to 14.7)	7.9 (7.1 to 9.0)	15.8 (13.9 to 17.7)	18.6 (16.1 to 22.2)
Accuracy — % (95% CI)‡				
1–P ₃₀				
Creatinine equation	12.8 (10.9 to 14.7)	16.6 (13.6 to 19.7)	10.2 (6.4 to 14.2)	7.8 (5.1 to 11.0)
Cystatin C equation	14.1 (12.2 to 16.2)	21.4 (18.2 to 24.9)	12.7 (8.5 to 17.4)	2.2 (0.6 to 3.9)
Creatinine–cystatin C equation	8.5 (7.0 to 10.2)	13.3 (10.7 to 16.1)	5.3 (2.7 to 8.2)	2.3 (0.9 to 4.2)
Average of creatinine and cystatin C equations†	8.2 (6.7 to 9.9)	12.1 (9.5 to 14.8)	6.4 (3.6 to 9.7)	2.9 (1.3 to 4.9)
1–P ₂₀				
Creatinine equation	32.9 (30.1 to 35.7)	37.2 (33.1 to 41.2)	31.1 (25.1 to 37.4)	26.5 (21.7 to 31.4)
Cystatin C equation	33.0 (30.3 to 35.7)	42.1 (38.2 to 46.1)	29.3 (23.6 to 35.4)	19.4 (15.4 to 23.7)
Creatinine–cystatin C equation	22.8 (20.4 to 25.2)	28.6 (25.1 to 32.4)	17.8 (13.3 to 22.9)	16.2 (12.4 to 20.5)
Average of creatinine and cystatin C equations†	23.7 (21.3 to 26.1)	29.1 (25.7 to 32.8)	17.6 (13.2 to 22.4)	18.8 (14.6 to 23.2)

BIS2: $767 \times \text{cystatin C}^{-0.61} \times \text{creatinine}^{-0.40} \times \text{age}^{-0.57} \times$
 0.87 (if female)
 CKD-EPI:

$$\text{eGFR} = 130 \times \text{cystatin C}^{-1.069} \times \text{age}^{-0.117} - 7,$$

$$\text{FAS}_{\text{cysC}} = \frac{107.3}{\frac{\text{ScysC}}{Q_{\text{cysC}}}} \times \left[0.988^{(\text{Age}-40)} \text{ when age} > 40 \text{ years} \right].$$

$$\text{FAS}_{\text{combi}} = \frac{107.3}{\alpha \times \frac{\text{Scr}}{Q_{\text{crea}}} + (1 - \alpha) \times \frac{\text{ScysC}}{Q_{\text{cysC}}}} \times \left[0.988^{(\text{Age}-40)} \text{ when age} > 40 \text{ years} \right].$$

Cystatine C

- + Combinée, pédiatrie
- “Cost-effectiveness?”
- Une certaine imprecision reste au niveau individuel

The applicability of eGFR equations to different populations

Pierre Delanaye and Christophe Mariat

Nat. Rev. Nephrol. 9, 513–522 (2013)

Performance of equations in specific populations

Performance of Creatinine-Based Estimates of GFR in Kidney Transplant Recipients: A Systematic Review

Christine A. White, MD,¹ David Huang, BSc,¹ Ayub Akbari, MD,^{2,3} Jocelyn Garland, MD,¹ and Greg A. Knoll, MD^{2,3,4}

Am J Kidney Dis 56:1140-1157.2008

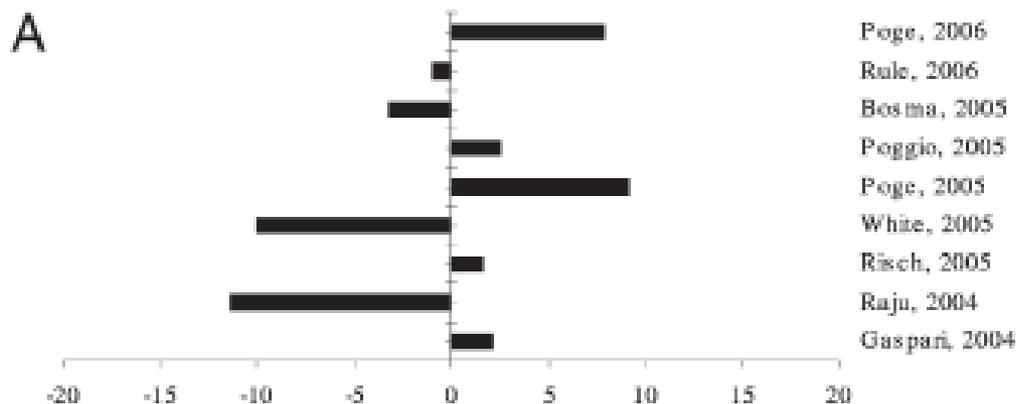


Table 3. Accuracy of Prediction Equations

Equations and Studies	Percent of Estimates Within		
	10%	20%	30%
4-Variable MDRD Study equation			
Poge et al, ³² 2006	25		67
Gera et al, ¹⁶ 2006			69
Bosma et al, ¹² 2005	38		88
Poggio et al, ²³ 2005		53	
Poge et al, ²² 2005	25		60
White et al, ³⁰ 2005	24		74
Risch & Huber, ²⁶ 2005			66
Raju et al, ²⁵ 2005			66
Gaspari et al, ¹⁴ 2004	44	76	
Pooled estimate (95% CI)			
All studies	35 (32-38)	59 (54-65)	76 (74-78)
High quality*	34 (32-37)	53 (46-60)	77 (75-79)

Relative Performance of the MDRD and CKD-EPI Equations for Estimating Glomerular Filtration Rate among Patients with Varied Clinical Presentations

Kazunori Murata,* Nikola A. Baumann,* Amy K. Saenger,* Timothy S. Larson,*† Andrew D. Rule,*† and John C. Lieske*†

MDRD= 80%

CKD-EPI= 78%

(n=1375, Clairance urinaire iothalamate)

CLINICAL AND TRANSLATIONAL RESEARCH

Estimating Glomerular Filtration Rate in Kidney Transplant Recipients: Performance Over Time of Four Creatinine-Based Formulas

Fanny Buron,¹ Aoumer Hadj-Aissa,² Laurence Dubourg,² Emmanuel Morelon,¹ Jean-Paul Steghens,³ Michel Ducher,⁴ and Jean-Pierre Fauvel^{4,5}

MDRD= 85%

CKD-EPI= 81%

(n=1249, Clairance urinaire d'inuline)

CLINICAL AND TRANSLATIONAL RESEARCH

MDRD Versus CKD-EPI Equation to Estimate Glomerular Filtration Rate in Kidney Transplant Recipients

Ingrid Masson,¹ Martin Flamant,² Nicolas Maillard,¹ Andrew D. Rule,³ François Vrtovsnik,⁴ Marie-Noëlle Peraldi,⁵ Lise Thibaudin,¹ Etienne Cavalier,⁶ Emmanuelle Vidal-Petiot,² Christine Bonneau,⁷ Olivier Moranne,⁸ Eric Alamartine,¹ Christophe Mariat,¹ and Pierre Delanaye^{9,10}

MDRD= 80%

CKD-EPI= 74%

(n=825, Clairance urinaire d'inuline/⁵¹Cr-EDTA)

Estimation of GFR by different creatinine- and cystatin-C-based equations in anorexia nervosa

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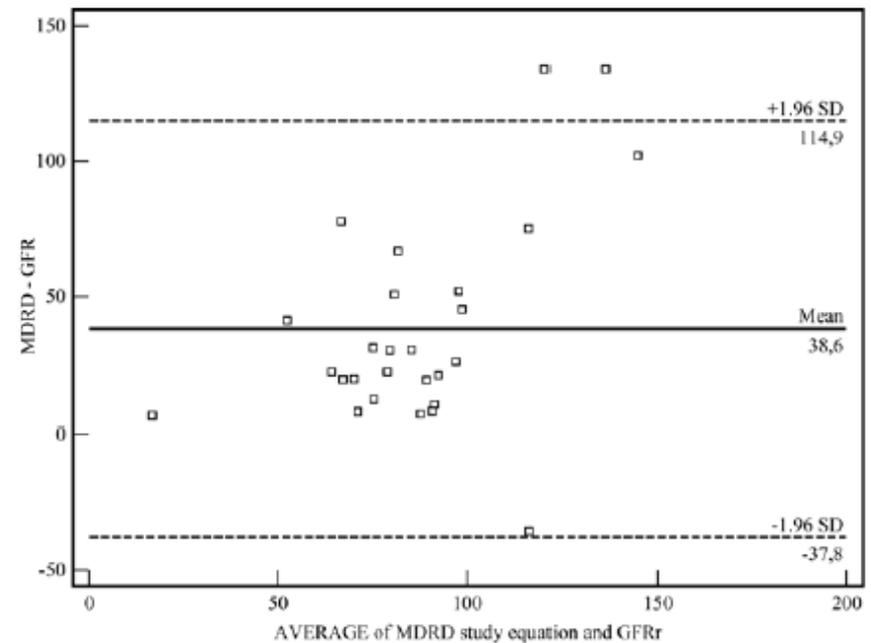
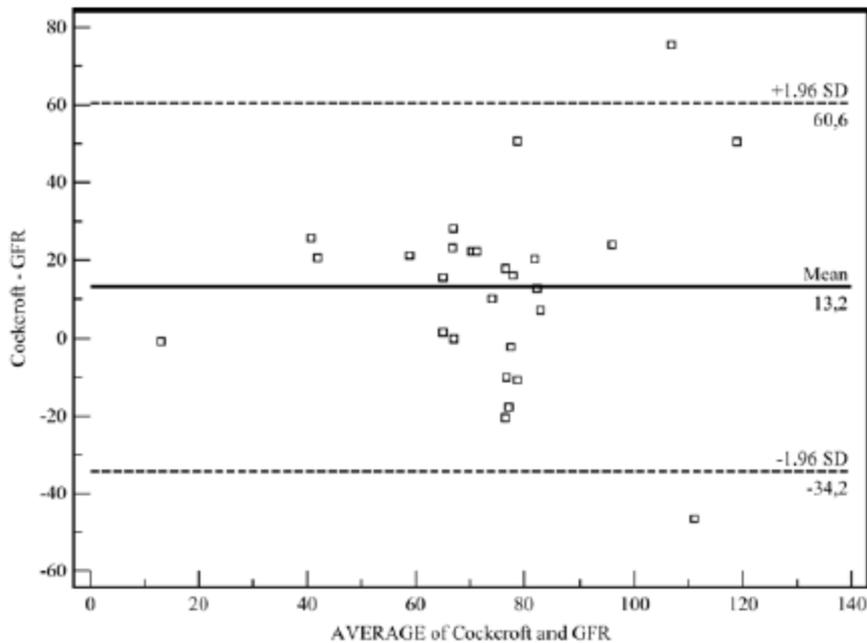
³Department of Diabetes, Nutrition and Metabolic Disorders, and

⁴Department of Nuclear Medicine, University of Liège, CHU Sart Tilman, Liège, Belgium

- n=27, ⁵¹Cr-EDTA, créatinine calibrée
- DFG moyen = 67 mL/min

	Mean difference with measured GFR (ml/min) for the whole population (n = 27)	SD of difference for the whole population
MDRD study	39	39
Cockcroft and Gault	13	24

If a relative difference was used, the estimated GFR was found within 30% measured GFR in 30% and 63% cases for the MDRD study and the Cockcroft and Gault equations,



Obèse

Cockcroft : très mauvais...

- Verhave JC, AJKD 2005
- Cirillo, NDT, 2005
- Rigalleau, Metab Clin Exper, 2005
- Froissart, JASN, 2006
- Cockcroft, Nephron, 1976
- Logique...poids dans l'équation...

Original Articles

Modification of Diet in Renal Disease versus Chronic Kidney Disease Epidemiology Collaboration equation to estimate glomerular filtration rate in obese patients

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François Vrtovsnik³,
Etienne Cavalier⁴,
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- Paris-Liège
- n=366, ⁵¹Cr-EDTA, créatinine calibrée

Main characteristics of the population, $n = 366$

Age (year)	55 ± 14 [18–86]
Female	185 (51%)
Weight (kg)	100 ± 22 [67–258]
Height (cm)	166 ± 10 [144–193]
African origin	50 (14%)
BMI (kg/m^2)	36 ± 7 [30–77]
30–35 kg/m^2	217 (59%)
35–40 kg/m^2	76 (21%)
>40 kg/m^2	73 (20%)

Table 2. Predictive performances of the MDRD study and CKD-EPI equations in the total obese population and according to different GFR levels

Population	Mean mGFR	Mean mGFR	Mean eGFR	Mean bias	Median bias (IQR)	Relative bias	Accuracy within 30%
	mL/min						%
Total							
MDRD	71 ± 35					± 28.7	80*
CKD-EPI	71 ± 35					± 30.0	76
mGFR < 30 mL/min/1.73 m² (n = ...)							
MDRD	26 ± 7					± 44.9	70*
CKD-EPI	26 ± 7					± 45.5	62
30 < mGFR < 59 mL/min/1.73 m²							
MDRD	55 ± 13					± 22.6	85*
CKD-EPI	55 ± 13					± 25.9	79
mGFR < 60 mL/min/1.73 m² (n = ...)							
MDRD	45 ± 18					± 32.0	80*
CKD-EPI	45 ± 18					± 33.9	73
60 < mGFR < 89 mL/min/1.73 m²							
MDRD	94 ± 17					± 24.1	79
CKD-EPI	94 ± 17					± 23.8	75
mGFR > 90 mL/min/1.73 m² (n = ...)							
MDRD	126 ± 15					± 19.0	87
CKD-EPI	126 ± 15					± 16.4	89
mGFR > 60 mL/min/1.73 m² (n = 100)							
MDRD	103 ± 22	81 ± 15	86 ± 21	4.6 ± 18.4*	2.1 (25.3)*	6.7 ± 23.2	81
CKD-EPI	103 ± 22	81 ± 15	91 ± 20	9.3 ± 17.2	8.5 (23.4)	12.7 ± 22.6	79

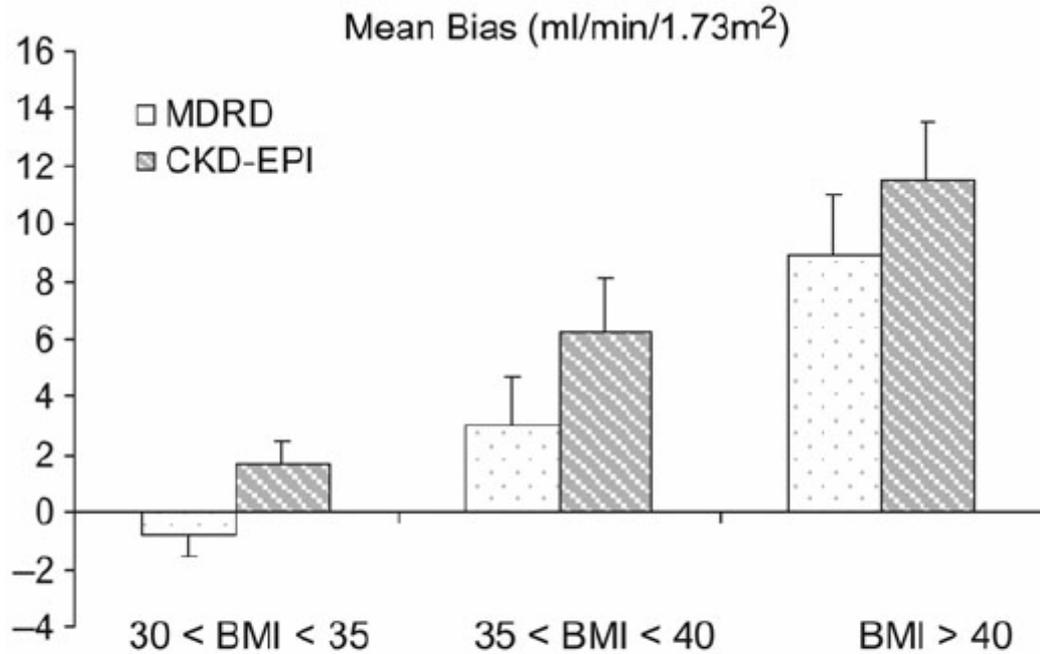


FIGURE 3: Mean bias of the MDRD and CKD-EPI equations in BMI subgroups. Mean bias is significantly lower for the MDRD equation and increases with BMI stage (two-way ANOVA test).

*P < 0.05 versus CKD-EPI. **P < 0.05 for SD versus CKD-EPI.

- CKD-EPI (and MDRD) surestiment DFG

OK mais c'est pas logique...

Impact de l'indexation par la BSA

- Impact majeur sur le DFG
- Sur-correction du DFG mesuré (DFG faussement bas)

Non-indexed mGFR (mL/min)	71 ± 35 [11-169]
CKD stage	
GFR ≥ 90 mL/min	110 (30%)
GFR 60-89 mL/min	100 (27%)
GFR 30-59 mL/min	107 (29%)
GFR 15-29 mL/min	44 (12%)
Hyperfiltrating status (GFR > 120 mL/min)	37 (10%)
Indexed mGFR (mL/min/1.73 m ²)	56 ± 26 [8-125]
CKD stage	
GFR ≥ 90 mL/min/1.73 m ²	44 (12%)
GFR 60-89 mL/min/1.73 m ²	114 (31%)
GFR 30-59 mL/min/1.73 m ²	137 (37%)
GFR 15-29 mL/min/1.73 m ²	62 (17%)
Hyperfiltrating status (GFR > 120 mL/min/1.73 m ²)	1 (<1%)

Delanaye P, NDT, 2005
Eriksen BO, JASN, 2011

The GFR and GFR decline cannot be accurately estimated in type 2 diabetics

Flavio Gaspari^{1,7}, Piero Ruggenti^{1,2,7}, Esteban Porrini^{1,3,7}, Nicola Motterlini¹, Antonio Cannata¹, Fabiola Carrara¹, Alejandro Jiménez Sosa³, Claudia Cella¹, Silvia Ferrari¹, Nadia Stucchi¹, Aneliya Parvanova¹, Ilian Iliev¹, Roberto Trevisan⁴, Antonio Bossi⁵, Jelka Zaletel⁶ and Giuseppe Remuzzi^{1,2}; for the GFR Study Investigators

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- **Diabétiques**
- **Iohexol**
- **n=600**
- **Hyperfiltrants (DFG>120 mL/min/1.73 m²) n=90**
- **MRC (<80 mL/min/1.73 m²) n=76**

	Accuracy		Bias		Precision	
	30%		Mean		SD	
	MDRD	CKD-EPI	MDRD	CKD-EPI	MDRD	CKD-EPI
All	85	91	-16	-13	17	16
Normofiltrating (80-120 mL/min/1.73 m ²)	88	96	-15	-11	14	12
Hypofiltrating (lower than 80 mL/min/1.73 m ²)	88	82	+0.6	+4	16	16
Hyperfiltrating (over 120 mL/min/1.73 m ²)	68	77	-33	-33	18	13

Tous les statuts « hyperfiltrants » sont loupés

Le sujet « âgé »



Comparaison des exactitudes à 30% -CKD-EPI vs BIS

- *Koppe L et al. J Nephrol, 2013*
 - **n=224, Mean Age=75** 72% vs 76%
- *Lopes M et al. BMC Nephrology, 2013*
 - **n=95, Mean Age=85** 75% vs 80%
- *Alshoer I et al. AJKD, 2014*
 - **n=394, Median Age=80** 83% vs 88%
- *Vidal-Petiot E et al. AJKD, 2014*
 - **N=609, Mean Age=76** 82% vs 84%

Comparing GFR Estimating Equations Using Cystatin C and Creatinine in Elderly Individuals

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J Am Soc Nephrol 26: 1982–1989, 2015.

N=805
+74 y

Equation	Bias Median Difference	Precision IQR	Accuracy P ₃₀
eGFR _{Cr}			
CKD-EPI	-2.7 (-3.3 to -2.1)	12.1 (11.2 to 13.4)	91.7 (89.9 to 93.4)
Japanese	10.5 (9.8 to 11.2) ^c	10.9 (9.7 to 12.1) ^a	86.3 (83.9 to 88.6) ^c
BIS	5.7 (5.1 to 6.4) ^c	11.9 (10.6 to 12.7) ^a	95.8 (94.4 to 97.1) ^b

^aNo different than CKD-EPI.

^bBetter than CKD-EPI.

^cWorse than CKD-EPI.

Comparison of glomerular filtration rate estimating equations derived from creatinine and cystatin C: validation in the Age, Gene/Environment Susceptibility-Reykjavik elderly cohort

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Table 2. Bias (median eGFR–mGFR, mL/min/1.73 m²), precision (IQR, mL/min/1.73 m²), absolute accuracy (median, percent) and P₃₀ accuracy (percentage of GFR estimated within 30% of mGFR) of GFR estimating equations based on creatinine and the combination of creatinine and cystatin C in the AGES-Kidney cohort (*n* = 805)

Variables	LMR _{Cr}	FAS _{Cr}	CKD-EPI _{Cr}	MEAN _{LMR+CAPA}	FAS _{Cr+Cys}	CKD-EPI _{Cr+Cys}
Bias	–4.8 (–5.4 to –4.2) ^a	–5.7 (–6.3 to –5.1) ^a	2.7 (2.1 to 3.3)	–2.7 (–3.2 to –2.1) ^a	–5.9 (–6.5 to –5.4) ^a	0.6 (–0.1 to 1.2)
Precision	10.8 (10.1 to 11.5) ^b	10.7 (9.9 to 11.9) ^b	12.1 (11.2 to 13.4)	9.3 (8.5 to 10.1) ^c	10.0 (9.1 to 10.9) ^c	10.2 (9.0 to 11.1)
Absolute accuracy	11.4 (10.3 to 12.3) ^c	12.1 (11.1 to 13.2) ^a	10.2 (9.3 to 11.0)	8.5 (8.0 to 9.2) ^c	11.3 (10.5 to 12.3) ^a	8.1 (7.5 to 8.9)
P ₃₀ accuracy	95.0 (93.5 to 96.5) ^b	95.8 (94.4 to 97.2) ^b	91.7 (89.9 to 93.4)	97.3 (96.2 to 98.4) ^b	97.8 (96.7 to 98.8) ^b	96.1 (94.8 to 97.4)

Data are presented with 95% CIs.

^aSignificantly worse (*P* < 0.05) than corresponding CKD-EPI equation.

^bSignificantly better (*P* < 0.05) than corresponding CKD-EPI equation.

^cNo statistical difference (*P* ≥ 0.05) compared with corresponding CKD-EPI equation.

Jonas Björk, Sten Erik Bäck, Natalie Ebert, Marie Evans, Anders Grubb, Magnus Hansson, Ian Jones, Edmund J. Lamb, Peter Martus, Elke Schaeffner, Per Sjöström and Ulf Nyman*

GFR estimation based on standardized creatinine and cystatin C: a European multicenter analysis in older adults

Table 2: Bias, precision and accuracy (95% confidence intervals) of creatinine, cystatin C and combined-marker equations in adults ≥ 70 years.

Equations	Bias	Precision	Absolute accuracy	P ₁₅ accuracy	P ₃₀ accuracy
Creatinine (n=3226)					
BIS1	1.7 (1.2 to 2.0)	11.6 (11.1–12.1)	14.8 (14.1–15.5)	50.7 (48.9–52.4)	77.5 (76.1–78.9)
BIS1 (no Berlin data, n=2569)	2.0 (1.6 to 2.4)	11.6 (11.1–12.1)	16.3 (15.5–17.1)	46.6 (44.7–51.1)	73.8 (72.1–75.5)
CKD-EPI	3.6 (3.2 to 4.0)	12.3 (11.9–13.0)	16.3 (15.6–17.0)	46.3 (44.6–48.0)	76.4 (74.9–77.9)
FAS	0.6 (0.3 to 0.9)	11.1 (10.6–11.5)	14.0 (13.4–14.5)	53.3 (51.5–55.0)	80.9 (79.5–82.3)
LMR	-0.7 (-1.0 to -0.4)	10.5 (10.1–11.0)	13.8 (13.3–14.3)	54.2 (52.4–55.9)	83.5 (82.2–84.8)
LMR (no Lund data, n=2309)	-1.0 (-1.5 to -0.6)	11.0 (10.5–11.6)	13.9 (13.3–14.4)	53.9 (51.8–55.9)	83.7 (82.2–85.2)
Cystatin C (n=2638)					
CAPA	-1.4 (-1.8 to -1.0)	11.9 (11.3–12.6)	15.7 (14.9–16.5)	48.2 (46.3–50.1)	80.3 (78.8–81.8)
CAPA (no Lund data, n=1721)	1.0 (0.5 to 1.6)	13.1 (12.3–13.8)	14.1 (13.3–15.0)	52.3 (49.9–54.7)	82.5 (80.7–84.3)
CKD-EPI	-2.7 (-3.1 to -2.3)	11.8 (11.3–12.5)	16.4 (15.7–17.1)	46.1 (44.2–48.0)	78.8 (77.3–80.4)
FAS	-1.1 (-1.6 to -0.8)	12.2 (11.7–12.8)	15.1 (14.3–16.0)	49.8 (47.9–51.8)	80.9 (79.4–82.4)
Creatinine + cystatin C (n=2638)					
BIS2	-1.2 (-1.5 to -0.8)	10.5 (10.0–11.0)	12.1 (11.6–12.8)	58.4 (56.5–60.3)	85.7 (84.4–87.0)
BIS2 (no Berlin data, n=1981)	-1.9 (-2.3 to -1.4)	10.9 (10.4–11.4)	14.0 (13.2–14.7)	52.7 (50.5–54.9)	82.6 (80.9–84.3)
CKD-EPI	-0.1 (-0.4 to 0.2)	10.2 (9.6–10.8)	12.8 (12.3–13.3)	56.8 (54.9–58.7)	86.8 (85.5–88.1)
FAS	-0.8 (-1.1 to -0.5)	10.1 (9.7–10.7)	12.2 (11.5–12.7)	58.7 (56.8–60.6)	85.7 (84.4–87.1)
MEAN _{LMR+CAPA}	-1.0 (-1.3 to -0.6)	9.2 (8.8–9.6)	11.9 (11.3–12.4)	61.4 (59.6–63.3)	88.7 (87.5–89.9)
MEAN _{LMR+CAPA} (no Lund data, n=1721)	0.1 (-0.3 to 0.6)	9.7 (9.1–10.3)	11.1 (10.6–11.8)	63.6 (61.4–65.9)	89.0 (87.5–90.5)

Median bias (eGFR–mGFR) and precision (interquartile range) expressed in mL/min/1.73 m², and median absolute accuracy ((eGFR–mGFR)/mGFR) expressed in percent, and P₁₅ and P₃₀ accuracy (percentage of GFR estimates within 15% and 30% of measured GFR).

5 cohortes > 70 y

Créatinine

Biais: pire pour CKD-EPI

Précision: mieux pour LM et FAS

Exactitude: LM>FAS>CKD-EPI

Cystatine C

Pas de différence avec créat

Combinée

+5 to 10% comparée à la créatinine

LM+CAPA légèrement meilleures

RESEARCH LETTER

Comparing Newer GFR Estimating Equations Using Creatinine and Cystatin C to the CKD-EPI Equations in Adults

	CKD-EPI Validation (n=3896)	CKD-EPI Development (n=8254)
Age (years)	49.5 ± 14.7	47.0 ± 14.8
<18	0 (0%)	0 (0%)
18-39	1066 (27%)	2921 (35%)
40-65	2262 (58%)	4309 (52%)
>65	568 (15%)	1024 (12%)
Sex		
Male	2129 (55%)	4648 (56%)
Female	1767 (45%)	3606 (44%)
Race		
Non-African American	3512 (90%)	5653 (68%)
African American	384 (10%)	2601 (32%)
Measured GFR (ml/min/1.73m ²)	67.9 ± 35.8	67.6 ± 39.6
Geographic regions	North America Europe	North America Europe
GFR measurement method	Urinary clearance of iothalamate and EDTA, plasma	Urinary clearance of iothalamate

Equation	Bias Median Difference (mL/min/1.73 m ²)	Precision IQR of Differences (mL/min/1.73 m ²)	Accuracy 1 – P ₃₀ (%)	Accuracy RMSE
Performance of Creatinine Equations in Creatinine Validation Database (n=3,896)				
CKD-EPI	2.2 (1.8, 2.6)	16.6 (15.8, 17.2)	15.8 (14.7, 17.0)	0.249 (0.240, 0.259)
LMR	7.4 (6.8, 7.8)	18.2 (17.6, 19.1)	20.3 (19.0, 21.6)	0.280 (0.272, 0.288)
FAS	1.4 (1.0, 1.8)	18.0 (17.3, 18.7)	18.3 (17.1, 19.5)	0.261 (0.252, 0.271)
Performance of Cystatin C Equations in Cystatin C Validation Database (n=1,119)				
CKD-EPI	3.4 (2.3, 4.4)	16.4 (14.8, 17.7)	14.1 (12.1, 16.2)	0.234 (0.220, 0.250)
CAPA	3.8 (2.7, 4.9)	18.2 (16.6, 19.6)	16.3 (14.1, 18.4)	0.247 (0.233, 0.264)
FAS	0.2 (–0.8, 1.4)	20.5 (18.6, 21.6)	23.9 (21.4, 26.5)	0.288 (0.270, 0.310)

Limitations des formules = créatinine

Populations spécifiques:
Les équations ne sont pas magiques!!
Gardons notre sens clinique!!

Anorexie nerveuse (Delanaye P, Clin Nephrol, 2009, 71, 482)

Cirrhose (Skluzacek PA, Am J Kidney Dis, 2003, 42, 1169)

USI (Delanaye P, BMC Nephrology, 2014, 15, 9)

Hospitalisés (Poggio ED, Am J Kidney Dis, 2005, 46, 242)

Greffés cœur (Delanaye P, Clin Transplant, 2006, 20, 596)

Greffés rein (Masson I, Transplantation, 2013, 95, 1211)

Obèse (Bouquegneau A, NDT, 2013, 28, iv122)

Conclusions: formules un message double? un double message ?

- Pour les non-néphrologues:
MDRD (ou CKD-EPI ou FAS) sont les moyens les plus simples pour estimer le DFG
- Pour les néphrologues:
MDRD (ou CKD-EPI ou FAS) ne sont pas magiques, elles ont toutes des limitations à connaître

The applicability of eGFR equations to different populations

Pierre Delanaye and Christophe Mariat

Aujourd'hui, la question n'est pas tant de savoir quelle équation est la meilleure mais quand un recours au DFG mesuré est pertinent

Merci de votre attention!

SFNDT 2020 à Liège



SOCIÉTÉ FRANCOPHONE
DE NÉPHROLOGIE
DIALYSE ET TRANSPLANTATION

Nous serons heureux de vous accueillir!!!



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