Original Article

A Comparison of the Renal Function between GFR from Tc-99m DTPA Renography and Serum Creatinine, Serum BUN, eGFR by CKD-EPI Equation, and 24-Hour Urine Creatinine Clearance in Thai Living Related Kidney Donors

Sunanta Chiewvit MD[1], Nuttasith Larpparisuth MD[2]

[1] Division of Nuclear Medicine, Department of Radiology, Siriraj Hospital, Mahidol University, Bangkok, Thailand

[2] Division of Nephrology, Department of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand

Background: There are many methods used to estimate renal function in routine clinical practice. Good correlation between glomerular filtration rate (GFR) by Tc-99m DTPA renal scan and inulin clearance is the gold standard method of determining GFR.

Objective: The aim of the present study was to evaluate renal function by GFR by Tc-99m DTPA renography and compare it between serum creatinine (Cr), serum blood urea nitrogen (BUN), estimated GFR (eGFR) by Chronic Kidney Disease Epidemiology Collaboration equation (CKD-EPI equation), and 24-hour urine creatinine clearance in Thai living related kidney donors. The secondary aim was to investigate whether age or body mass index (BMI) would have a significant effect to the evaluation of GFR from Tc-99m DTPA renography.

Materials and Methods: The present study was a retrospective study that included potential living kidney donors who underwent Tc-99m DTPA renal scan and renogram at Siriraj Hospital (Bangkok, Thailand) to evaluate renal function between January 2011 and January 2018. All included patients had complete GFR data from Tc-99m DTPA renography, serum Cr, serum BUN, eGFR by CKD-EPI equation, and 24-hour urine creatinine clearance. Age, gender, and BMI data were also collected.

Results: One hundred twenty cases were included. There were 72 females and 48 males, and the mean age was 36.72±10.22 years with a range of 19 to 58 years. Significant correlation was observed between GFR from Tc-99m DTPA renography and serum Cr, serum BUN, eGFR by CKD-EPI equation, and 24-hour urine creatinine clearance. In contrast, gender and BMI revealed no significance with GFR from Tc-99m DTPA renography. Significant negative correlation was found between GFR from Tc-99m DTPA renography and age.

Conclusion: The results of the present study revealed that serum Cr, serum BUN, eGFR by CKD-EPI equation, and 24-hour urine creatinine clearance were reliable methods for evaluating GFR. Older age significantly correlated with reduction of the GFR value from Tc-99m DTPA renography.

Keywords: GFR; Renal function; Glomerular filtration rate; Tc-99m DTPA renography; Serum creatinine; BUN; CKD-EPI equation; Urine 24 hours creatinine clearance

Received 6 November 2019 | Revised 13 June 2022 | Accepted 15 June 2022

J Med Assoc Thai 2022;105(8):729-33

Website: http://www.jmatonline.com

The best index of renal function is glomerular filtration rate (GFR). Normal GFR value in male is 127 to 130 mL/minute/1.73 m² and normal GFR value in female is 118 to 120 mL/minute/1.73 m²[1,2]. GFR can be measured by filtration markers like inulin clearance, which is a gold standard method, but it is costly, complicated, and not widely available. Serum creatinine (Cr) is another renal function marker used in routine clinical practice. It is easy and inexpensive technique, but estimated GFR (eGFR) by serum Cr may not be sufficiently accurate[3]. Cr level is influenced by non-renal factors, including muscle mass, age, and the actual method of measurement[4,5]. Creatinine clearance calculation is estimated from serum Cr level with mathematical formulas. These equations include Chronic Kidney Disease Epidemiology Collaboration equation (CKD-EPI equation), Cockcroft-Gault formula, Modified Diet in Renal Disease-4 (MDRD-4) and MDRD-6, and

Correspondence to:

Chiewvit S.

Division of Nuclear Medicine, Department of Radiology, Faculty of Medicine Siriraj Hospital, Mahidol University, 2 Wanglang Road, Bangkoknoi, Bangkok 10700, Thailand.

Phone: +66-2-4196220, **Fax**: +66-2-4113341

Email: schiewvit1@hotmail.com

How to cite this article:

Chiewvit S, Larpparisuth N. A Comparison of the Renal Function between GFR from Tc-99m DTPA Renography and Serum Creatinine, Serum BUN, eGFR by CKD-EPI Equation, and 24-Hour Urine Creatinine Clearance in Thai Living Related Kidney Donors. J Med Assoc Thai 2022;105:729-33.

DOI: 10.35755/jmedassocthai.2022.08.10778

Schwartz equation for pediatric patients. Among these equations CKD-EPI is the most accurate method for global GFR estimation[6,7]. Blood urea nitrogen (BUN) is less reliable than Cr to predict renal function. The increase of BUN from extrarenal causes are rich protein diets or tissue breakdown from bleeding, muscle trauma, or steroid administration. On the other hand, the reduction of BUN from non-renal causes are a very low protein diet or liver failure[8,9].

Twenty-four-hour urine creatinine clearance is widely used to measure GFR, however, the accuracy is dependent on correct time of urine collection. The calculation of the 24-hour urine creatinine clearance is made by multiplying urine creatinine concentration and urine volume and divide it by the serum Cr concentration.

However, the 24-hour urine creatinine clearance calculation by this formula is susceptible to overestimate the real GFR by 10% to 20% depending upon the proportion of urinary creatinine that originate from the tubular secretion[10]. Alternatively, measurement of GFR by Tc-99m diethylenetriaminepentaacetic acid (DTPA) is simple, non-invasive, has high precision, and is able to evaluate the split renal function. Tc-99m DTPA can be filtered by glomeruli rather than reabsorbed or excreted by kidney tubules. Good correlation was previously reported between Tc-99m DTPA and inulin clearance[11]. Tc-99m DTPA clearance can accurately reflect GFR and can replace inulin clearance as the gold standard method of determining GFR for scientific research.

The aim of the present study was to evaluate renal function by comparing between GFR from Tc-99m DTPA renography and serum Cr, serum BUN, eGFR by CKD-EPI equation, and 24-hour urine creatinine clearance in Thai living related kidney donors. The secondary aim was to investigate whether age or body mass index (BMI) will have a significant effect to the evaluation of GFR by Tc-99m DTPA renography.

Materials and Methods

Subject

The present study was a retrospective study that evaluated 150 potential kidney donors who underwent Tc-99m DTPA renal scan and renogram to evaluate renal function between January 2011 and January 2018. Of those, 30 cases were excluded due to incomplete data, as follows, missing data for 24-hour urine creatinine clearance (n=20), missing serum BUN data (n=5), missing BUN and 24-hour urine creatinine clearance data (n=2), and missing serum BUN, serum Cr, and 24-hour urine creatinine clearance data (n=3). The remaining 120 cases were studied. The gender proportion breakdown was 72 females and 48 males, with the mean age of donors of 36.72±10.22 years and a range of 19 to 58 years. Collected data included age, gender, weight, height, BMI, BUN, Cr, eGFR by CKD-EPI equation, and 24-hour urine creatinine clearance. The Ethics Committee of the Faculty of Medicine Siriraj Hospital, Mahidol University approved the present study (SIRB COA no. Si319/2018).

Table 1. General descriptive data of the study subjects (n=120)

Characteristics	Max	Min	Mean±SD
GFR by Tc-99m DTPA (mL/minute)	154.90	64.44	103.23±18.83
Serum creatinine (mg/dL)	1.35	0.48	0.82±0.17
Serum BUN (mg/dL)	20	3.7	11.41±2.93
eGFR by CKD-EPI equation (mL/minute)	166.50	66.60	102.83±16.03
Urine 24 hours creatinine clearance (mL/minute)	250.84	44.91	110.11±32.76
Age (year)	58	19	36.72±10.22
Height (cm)	193	144	162.98±9.44
Weight (kg)	96	42	65.16±12.97
BMI (kg/m^2)	36	16.16	24.44±3.89

Max=maximum; Min=minimum; SD=standard deviation; GFR=glomerular filtration rate; DTPA=diethylenetriaminepentaacetic acid; BUN=blood urea nitrogen; eGFR=estimated GFR; CKD-EPI=Chronic Kidney Disease Epidemiology Collaboration; BMI=body mass index

Statistical analysis

All statistical analyses were performed using SPSS Statistics, version 16.0 (SPSS Inc., Chicago, IL, USA). Correlations between GFR by Tc-99m DTPA renography, Cr, BUN, eGFR by CKD-EPI equation, and 24-hour urine creatinine clearance were determined by paired samples t-test. Factor effect GFR by Tc-99m DTPA renography and age, gender, and BMI were evaluated using linear regression analysis. A p-value of less than 0.05 was regarded as being statistically significant.

Results

The maximum, minimum, mean, and standard deviation of GFR by Tc-99m DTPA renography, Cr, BUN, eGFR by CKD-EPI equation, 24-hour urine creatinine clearance, age, height, weight, and BMI in 120 living related kidney donors are shown in Table 1.

The present study analysis revealed significant correlation between GFR by Tc-99m DTPA renography and serum Cr, serum BUN, eGFR by CKD-EPI equation, and 24-hour urine creatinine clearance, as shown in Table 2.

Mean GFR by Tc-99m DTPA renography by

Table 2. Analysis for correlation between GFR by Tc-99m DTPA renography and serum creatinine, serum BUN, eGFR by CKD-EPI equation, and 24-hour urine creatinine clearance

Renal function parameter	p-value
Serum creatinine	0.002
Serum BUN	0.009
eGFR by CKD-EPI equation	<0.001
Urine 24 hours creatinine clearance	0.046

GFR=estimated glomerular filtration rate; DTPA=diethylenetriamine-pentaacetic acid; BUN=blood urea nitrogen; eGFR=estimated GFR; CKD-EPI=Chronic Kidney Disease Epidemiology Collaboration

p<0.05 indicates statistical significance

Table 3. Mean GFR by Tc-99m DTPA renography by gender, age and BMI subgroups (n=120)

Factor	Grouping	No. of patients	Mean GFR (mL/minute)
Sex	Male	48	100.71
	Female	72	104.25
Age(year)	<30	36	111.54
	31 to 40	39	103.79
	41 to 50	33	96.6
	>51	12	90.7
BMI (kg/m^2)	<25	83	101.98
	>25	37	104.75

GFR=glomerular filtration rate; BMI=body mass index

gender, age, and BMI are presented in Table 3. Age was found to be significantly associated with GFR by Tc-99m DTPA renography. However, no significant association was observed for gender or BMI. Linear regression analyses to evaluate association between GFR by Tc-99m DTPA renography and age and BMI are shown in Figure 1 and 2, respectively.

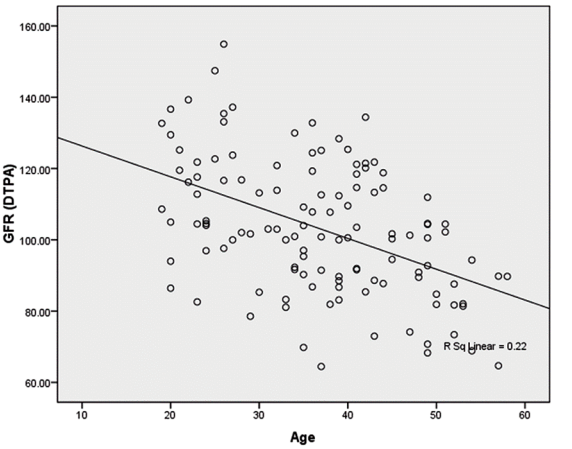

Figure 1. Linear regression analysis revealed a significant negative association between glomerular filtration rate (GFR) by Tc-99m DTPA renography and age.

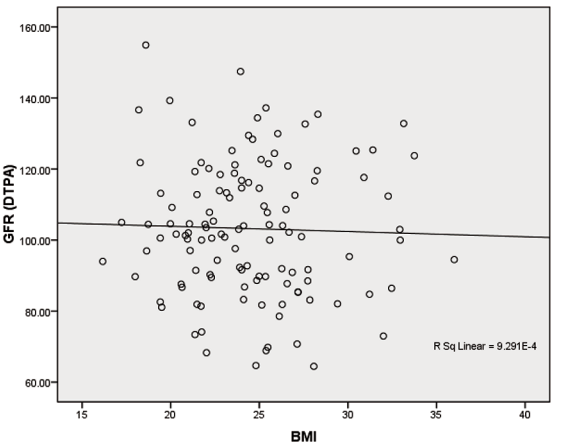

Figure 2. Linear regression analysis revealed no significant association between glomerular filtration rate (GFR) by Tc-99m DTPA renography and body mass index (BMI).

Discussion

GFR is the indicator of kidney function for the diagnosis, staging, and treatment of kidney disease. Renal dynamic imaging by Tc-99m DTPA is a minimally invasive, accurate, and repeatable method for evaluating GFR in living kidney donors. In the present study, the authors found significant relationship between GFR by Tc-99m DTPA renography and serum Cr, serum BUN, eGFR by CKD-EPI equation, and 24-hour urine creatinine clearance. Regarding the present study analysis to evaluate for association between GFR by Tc-99m DTPA renography and age and BMI, the authors found significant negative association for age, but not for BMI.

Estimated GFR by CKD-EPI equation is a measurement technique that is routinely used in the authors' hospital to evaluate renal function due to its simplicity, fast, convenience, and affordability. Moreover, patients are not exposed to radiation. However, the limitation of eGFR by CKD-EPI equation is vulnerable by non-renal factors such as muscle mass and age and cannot evaluate split renal function. The present study results revealed a significant correlation between GFR by Tc-99m DTPA renography and eGFR by CKD-EPI equation.

Regarding the relationship between GFR by Tc-99m DTPA renography and age, the present study and other previous studies observed a significantly lower GFR value in older patients. Mean GFR was 100 mL/minute/1.73 m² until 35 years of age, followed by a linear decline in GFR value that was more accelerated in females than in males at 7.7 versus

Table 4. Mean GFR by Tc-99m DTPA renography among different age groups from a study by Zhao et al[14]

Age (year)	n	GFR (mL/minute/1.73 m^2); mean±SD
20 to 29	52	88.2±12
30 to 39	44	91.8±14.4
40 to 49	38	89.4±11.4
>50	27	88.2±13.2

GFR=glomerular filtration rate; SD=standard deviation

Table 5. Mean eGFR among different BMI groups from a study by Kawamoto et al[15]

BMI (kg/m^2)	n	eGFR (mL/minute/1.73 m^2); mean±SD
<18.5	100	85.6±17.8
18.5 to 21.9	579	85.9±17.2
22.0 to 24.9	620	82.6±16.2
>25.0	417	82.6±16.7

eGFR=estimated glomerular filtration rate; BMI=body mass index

6.6 mL/minute/1.73 m^2/decade[12]. Decreased GFR in older patients may be due to nephron loss that may be secondary to glomerulosclerosis and renal microvascular disease[13].

Zhao et al[14] reported different results than those observed in the present study. Specifically, that study found no significant differences among age groups, and their oldest patient was 62 years compared to the present study oldest patient, which was aged 58 years (Table 4). The GFR by Tc-99m DTPA renography in the Zhao study was lower than the GFR by Tc-99m DTPA renography in the present study.

Regarding the relationship between GFR by Tc-99m DTPA renography and BMI, the authors found no significant association, which is in contrast to the significant relationship observed between these variables reported by Kawamoto et al[15] that reported upper normal weight and overweight or obese status to be associated with mild reduction in eGFR when compared with low or normal BMI (Table 5).

The mechanisms that lead to reduction in eGFR in overweight and obese individuals are not completely understood. Increased BMI are more likely to develop diabetes and hypertension, which can contribute to CKD.

Nautiyal et al[16] used the Gates Method of GFR estimation using a gamma camera. They found significant correlation when using the plasma sample technique in people with normal BMI, so this should be considered the investigation of choice for estimation of GFR in the normal BMI group. Among people with a BMI outside the normal range, GFR can be underestimated, so it is recommended that CT-based renal depth calculation technique be used as it has a better accuracy in these groups.

Limitation

Limitations of the present study must be considered. First, the present study was a single-center study. Second, the definition of GFR by Tc-99m DTPA renography, serum Cr, serum BUN, eGFR by CKD-EPI equation, and 24-hour urine creatinine clearance was based on a single assessment that could have been inaccurate. Third, the present study included only living related kidney donors that were assumed to have normal kidney function. As such, the present study results do not reflect a comparison of GFR measurement methods among patients with renal impairment. Fourth and last, measurement of GFR by gold standard inulin method was not available for use in the present study.

Conclusion

The results of the present study revealed significant correlation between GFR by Tc-99m DTPA renography and serum Cr, serum BUN, eGFR by CKD-EPI equation, and 24-hour urine creatinine clearance among living related kidney donors. Significant negative correlation was found between GFR by Tc-99m DTPA renography and age. This is in contrast to BMI, which had no effect.

What is already known on this topic?

Older age and high BMI are the factors that cause of decreased GFR.

What this study adds?

Significant correlation between GFR by Tc-99m DTPA renography and serum Cr, serum BUN, eGFR by CKD-EPI equation, and 24-hour urine creatinine clearance has been found. Significant negative correlation was found between GFR by Tc-99m DTPA renography and age. This is in contrast to BMI, which had no effect. BMI of more than 25 and less than 39 can be the kidney donor subject.

Acknowledgement

The authors gratefully acknowledge Ms. Dollaporn Polyeam for assistance with statistical analyses.

Conflicts of interest

The authors declare no conflict of interest.

References

1. Smith HW. Comparative physiology of the kidney. In: Smith HW, editor. The kidney: structure and function in health and disease. New York: Oxford University Press; 1951. p. 520-74.
2. Wesson LG. Renal hemodynamics in physiologic states. In: Wesson LG, editor. Physiology of the human kidney. New York: Grune & Stratton; 1969. p. 96-108.
3. Shemesh O, Golbetz H, Kriss JP, Myers BD. Limitations of creatinine as a filtration marker in glomerulopathic patients. Kidney Int 1985;28:830-8.
4. Levey AS, Bosch JP, Lewis JB, Greene T, Rogers N, Roth D. A more accurate method to estimate glomerular filtration rate from serum creatinine: a new prediction equation. Modification of Diet in Renal Disease Study Group. Ann Intern Med 1999;130:461-70.
5. Mula-Abed WA, Al Rasadi K, Al-Riyami D. Estimated Glomerular Filtration Rate (eGFR): A serum creatinine-based test for the detection of chronic kidney disease and its impact on clinical practice. Oman Med J 2012;27:108-13.
6. Fan L, Inker LA, Rossert J, Froissart M, Rossing P, Mauer M, et al. Glomerular filtration rate estimation using cystatin C alone or combined with creatinine as a confirmatory test. Nephrol Dial Transplant 2014;29:1195-203.
7. Teo BW, Xu H, Koh YY, Li J, Subramanian S, Sinha AK, et al. Glomerular filtration rates in healthy Asians without kidney disease. Nephrology (Carlton) 2014;19:72-9.
8. Levey AS. Measurement of renal function in chronic renal disease. Kidney Int 1990;38:167-84.
9. Dossetor JB. Creatininemia versus uremia. The relative significance of blood urea nitrogen and serum creatinine concentrations in azotemia. Ann Intern Med 1966;65:1287-99.
10. van Acker BA, Koomen GC, Koopman MG, de Waart DR, Arisz L. Creatinine clearance during cimetidine administration for measurement of glomerular filtration rate. Lancet 1992;340:1326-9.
11. Gunasekera RD, Allison DJ, Peters AM. Glomerular filtration rate in relation to extracellular fluid volume: similarity between 99mTc-DTPA and inulin. Eur J Nucl Med 1996;23:49-54.
12. Fenton A, Montgomery E, Nightingale P, Peters AM, Sheerin N, Wroe AC, et al. Glomerular filtration rate: new age- and gender- specific reference ranges and thresholds for living kidney donation. BMC Nephrol 2018;19:336.
13. Fuiano G, Sund S, Mazza G, Rosa M, Caglioti A, Gallo G, et al. Renal hemodynamic response to maximal vasodilating stimulus in healthy older subjects. Kidney Int 2001;59:1052-8.
14. Zhao X, Shao Y, Wang Y, Tian J, Sun B, Ru Y, et al. New normal values not related to age and sex, of glomerular filtration rate by (99m)Tc-DTPA renal dynamic imaging, for the evaluation of living kidney graft donors. Hell J Nucl Med 2012;15:210-4.
15. Kawamoto R, Kohara K, Tabara Y, Miki T, Ohtsuka N, Kusunoki T, et al. An association between body mass index and estimated glomerular filtration rate. Hypertens Res 2008;31:1559-64.
16. Nautiyal A, Mukherjee A, Mitra D, Chatterjee P, Roy A. Impact of body mass index on gates method of glomerular filtration rate estimation: A comparative study with single plasma sample method. Indian J Nucl Med 2019;34:19-23.