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CLINICAL STUDY

Comparison of Different Glomerular Filtration Methods in the Elderly: Which Formula Provides Better Estimates?

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Abstract

Objectives: Technetium-99m diethylenetriaminepentaacetic acid (^{99m}Tc-DTPA) is an ideal radioisotopic method having a high correlation with inulin clearance for the determination of glomerular filtration rate (GFR). Different formulas like creatinine clearance (CrCl) in 24 h urine samples, Cockroft–Gault formula (CGF), and modification of diet in renal disease (MDRD) are being used to come up with an estimate. In this study, we compared ^{99m}Tc-DTPA with the formulas mentioned above in an attempt to best identify the method that would yield the nearly ideal GFR estimates in the elderly. *Materials and methods*: In 76 patients who were admitted to our clinic, we measured 24 h urine volume (V), urine creatinine (Ucr), and serum creatinine (Scr) levels together with CrCl, Scr, serum urea (Su), and albumin (Alb) levels. By using coefficients identified for age, gender, and race, we calculated modification of diet in renal disease 1 (MDRD1). Different from MDRD1, we calculated modification of diet in renal disease 2 (MDRD2) that does not include Su and Alb parameters and formulas like CGF that include Scr, age, gender, and weight parameters to come up with GFR levels. All patients underwent ^{99m}Tc-DTPA procedure. *Results*: The mean of the GFR values measured by ^{99m}Tc-DTPA was 54.3 ± 19.9. The means of GFR values calculated by CrCl, MDRD1, MDRD2, and CGF were 58.0 ± 30.5, 60.9 ± 22.1, 54.4 ± 20.1, and 57.9 ± 22.4, respectively. GFR as measured by ^{99m}Tc-DTPA showed statistically significant correlations with the results of other methods ($p < 0.001$ for all methods). The most significant correlation was with MDRD1. *Conclusion*: MDRD1 can be used for next to ideal and accurate predictions of GFR in the elderly in the daily practice.

Keywords: elderly, kidney function, glomerular filtration rate, glomerular filtration methods, modification of diet in renal disease

INTRODUCTION

Together with aging, kidneys go through structural and functional changes as is true for other organs. The most ideal test that reflects renal function is "Glomerular Filtration Rate" (GFR). The amount of glomerular filtrate produced by both kidneys is called "GFR."[1]

The studies performed in the field demonstrate that after 30 years of age, GFR decreases by 0.8 mL/min each year.[2] In the 2002 guideline of National Kidney Foundation/Kidney Disease Outcomes Initiative (NKF/KDOQI), chronic renal disease (CRD) is classified into five stages based on GFR. In this guideline, having GFR below 60 mL/min/1.73 m^2 for more than 3 months is defined as "CRD."[3]

Decreases in GFR are regarded as a risk factor for cardiovascular mortality and morbidity especially in the elderly. Several studies have demonstrated that levels of GFR at or below 60 mL/min are together with increased cardiovascular risks.[4]

In our daily routine, serum creatinine (Scr) is used for estimating kidney functions; however, this is not a reliable marker in the elderly. Even if the elderly have GFR values way below the acceptable, they can have Scr within normal limits.

Because of the disadvantages brought forward by the use of Scr, there came the need to use different methods for the calculation of GFR. The golden standard for the calculation of GFR is the "inulin clearance."[5] Yet, the implementation of this method

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is cumbersome and costly. Another alternative is to measure GFR with radioisotopes. Radioactive isotopes like technetium-99m diethylenetriaminepentaacetic acid (^{99m}TC-DTPA), ^{125}I-iothalamate, and Chromium 51-ethylenediaminetetraacetic acid (^{51}Cr-EDTA) are used to measure GFR. These substances harbor several features of inulin and as the studies demonstrate they have high levels of correlation with inulin clearance. These methods have disadvantages like being costly or not being implementable at each and every center.[6]

These disadvantages led clinicians to develop formulas that are more practical, cheap, and that yield results close to the ideal. Formulas like Cockgroft–Gault formula (CGF), modification of diet in renal disease (MDRD), and 24 h urine creatinine (Ucr) clearance responded to this need. In studies comparing these formulas with methods accepted as reference, they were shown to estimate GFR values close to normal.

However, none of the most commonly used formulas could provide an accurate or optimal result even in the young adults. Among the CGF and MDRD formulas, there were significant differences for patients above the age of 65 years.

To this end, in elderly under high risk for kidney failure, we planned to compare the methods used for estimating GFR. In studies of inulin clearance, ^{99m}Tc-DTPA showed high correlation and was easier to prepare, more practical, and cheaper when compared to other radioisotopic methods.[7] As this method was easy to implement in our hospital, we identified it as a reference and measured GFR with ^{99m}Tc-DTPA. We compared other methods commonly used in routine practice like 24 h urine creatinine clearance (CrCl), MDRD, and CGF with the reference method.

MATERIALS AND METHODS

Collection of Data

The study was conducted on 76 hospitalized patients and followed up in Ankara University, School of Medicine, Department of Geriatric Medicine. Within the 3 months following the planning of the study, all the patients admitted to our clinic were recruited without any gender preference. The patients who had limited cognitive and functional capacity that would not allow for urine collection and those with acute renal failure and edema were excluded from the study. All the patients were informed about the study and consent forms were obtained.

We measured 24 h urine volume (V), Ucr, and Scr levels together with CrCl, Scr, blood urea nitrogen (BUN), and albumin (Alb) levels. By using coefficients identified for age, gender, and race, we calculated modification of diet in renal disease 1 (MDRD1). Different from MDRD1, we calculated modification of diet in renal disease 2 (MDRD2) that does not include BUN and Alb parameters and formulas like CGF that include Scr, age, gender, and weight parameters to come up with GFR levels.

For calculating CrCl, after discarding the first urine in the morning, the collection was started at 8:00 a.m. to be finished at 8:00 a.m. next morning covering 24 h. The collected urine was stored in line with the procedures. The amount of creatinine in 24 h urine sample, V, and Scr were calculated according to the CrCl formula:

$$\mathrm{CrCl} = \frac{\mathrm{Ucr} \times \mathrm{V}}{\mathrm{Scr} \times 1440}$$

GFR was calculated for each patient with MDRD1, MDRD2, and CGF:

$$\mathrm{MDRD1} = 170 \times \mathrm{Scr}^{-0.999} \times \mathrm{age}^{-0.176} \times (0.762 \text{ if female}) \times (1.180 \text{ if black}) \times \mathrm{Su}^{-0.170} \times \mathrm{Alb}^{+0.31}$$

(Su = BUN)

$$\mathrm{MDRD2} = 186 \times \mathrm{Scr}^{-1.154} \times \mathrm{age}^{-0.203} \times (0.742 \text{ if female}) \times (1.212 \text{ if black})$$

$$\mathrm{CGF} = \left[\frac{(140 - \mathrm{age}) \times \mathrm{weight\,(kg)}}{72 \times \mathrm{Scr}}\right] \times 0.85 \text{ if female}$$

Following the completion of urine collection at the Department of Nuclear Medicine, patients underwent GFR measurement procedure with ^{99m}Tc-DTPA. Up until at least 3 days prior to the implementation of this procedure, attention was paid to ensure that the patients would not use any radioisotopic substances for any scintigraphic procedures. All patients were hydrated with 500 mL of water 30 min prior to the procedure. Existing diseases, height, and weight measurements of the patients were reported to the physician implementing the procedure at the Department of Nuclear Medicine.

Preparation of ^{99m}Tc-DTPA

Guidelines prepared by the Turkish Society of Nuclear Medicine were used for the nuclear medicine examinations. This guideline was prepared and implemented in line with the similar guidelines available in North America and Europe.

As for the DTPA kits, TechneScan® kits manufactured by Mallinckrodt Company (St. Louis, MO, USA) were used. The radiopharmaceutical to be used was prepared fresh each test day by binding DTPA with fresh ^{99m}Tc in line with the kit insert. The bound kits were ready for use after incubation for 15 min at room temperature. In all patients, the dose to be administered was measured at the dose calibrator and was given as 5 mCi (185 MBq) ^{99m}Tc-DTPA in a volume of 0.5 mL.

Procedure for Obtaining Scans with Gamma Cameras

For scintigraphic images, General Electric Brand Starcam® (New York, NY, USA) 4000İ gamma camera

was used. Low-energy parallel whole collimator was used together with Gates protocol in the package software found in the computer system. The patient was placed in the supine position with the detector at the posterior. It was adjusted to cover both kidneys and the radiopharmaceutical substance was administered as a bolus by the intravenous (IV) route. A total of 24 images were obtained with 64 × 64 matrix throughout 6 min dynamically. After the images were recorded on the system, GFR values were calculated for each kidney separately and as a total value with the help of the computer program.

Statistical Analysis

SPSS (Version 15.0; SPSS Inc., Chicago, IL, USA) statistical package program was used for the evaluation of data. Camera technique employed with ^{99m}Tc-DTPA for the identification of GFR value was compared with CrCl, MDRD1, MDRD2, and CGF in 24 h urine with Spearman's correlation analysis. The coefficient (r) identified in this analysis was used to compare the correlation of the methods with each other. A value of $p < 0.05$ was accepted as being statistically significant.

RESULTS

A total of 76 patients were recruited in the study and they had a mean age of 72.8 ± 5.3 years. The basal demographical features of the patients are presented in Table 1.

For the patients in the study group, the mean GFR value calculated with ^{99m}Tc-DTPA was 54.3 ± 19.9. The mean GFRs of the CrCl, MDRD1, MDRD2, and CGF were 58.0 ± 30.5, 60.9 ± 22.1, 54.4 ± 20.1, and 57.9 ± 22.4, respectively (Table 2).

Nineteen patients (25%) had an established diagnosis of CRD. However, based on GFR values calculated with ^{99m}Tc-DTPA, 45 patients (59.21%) had values of 60 mL/min or lower accepted as threshold for CRD by NKF/KDOQI guideline.

The correlation of the patients with GFR values calculated with different methods is presented in Table 3.

Table 1. Demographic characteristics of study population.

Number	76
Age (years) (mean ± SD)	72.8 ± 5.3
Gender (male/female)	21/55
BMI (mean ± SD) (kg/m^2)	28.9 ± 5.5
Diabetes mellitus (n) (%)	32 (42.1)
Hypertension (n) (%)	59 (77.6)
Chronic renal disease (n) (%)	19 (25)
Congestive heart failure (n) (%)	14 (18.4)
Serum Alb (mean ± SD) (g/dL)	3.9 ± 0.4
Scr (mean ± SD) (mg/dL)	1.2 ± 0.6
Ucr (mean ± SD)(mg/dL)	779.4 ± 266.7
BUN (mean ± SD) (mg/dL)	48.3 ± 27.9

Note: BMI, body mass index; Alb, albumin; Scr, serum creatinine; Ucr, urine creatinine; BUN, blood urea nitrogen.

Table 2. GFR values calculated by using different methods.

	GFR (mean ± SD) (min–max) ($n = 76$)
^{99m}Tc-DTPA	54.3 ± 19.9 (8.1–99.1)
MDRD1	60.9 ± 22.1 (10.9–124.0)
MDRD2	54.4 ± 20.1 (11.0–120.0)
CGF	57.9 ± 22.4 (13.7–121.6)
CrCl	58.0 ± 30.5 (7.1–177.0)

Notes: GFR, glomerular filtration rate; ^{99m}Tc-DTPA, technetium-99m diethylenetriaminepentaacetic acid; MDRD1, modification of diet in renal disease 1, MDRD2, modification of diet in renal disease 2; CGF, Cockroft–Gault formula; CrCl, creatinine clearance.

Table 3. Correlation analyses of the GFR methods (r values).

	DTPA	CrCl	MDRD1	MDRD2	CGF
DTPA	1.00*	0.59*	0.70*	0.68*	0.69*
CrCl	0.59*	1.00*	0.73*	0.78*	0.71*
MDRD1	0.70*	0.73*	1.00*	0.97*	0.85*
MDRD2	0.68*	0.78*	0.97*	1.00*	0.85*
CGF	0.69*	0.71*	0.85*	0.85*	1.00*

Notes: GFR, glomerular filtration rate; DTPA, diethylenetriaminepentaacetic acid; CrCl, creatinine clearance; MDRD1, modification of diet in renal disease 1, MDRD2, modification of diet in renal disease 2; CGF, Cockroft–Gault formula.
*$p < 0.001$.

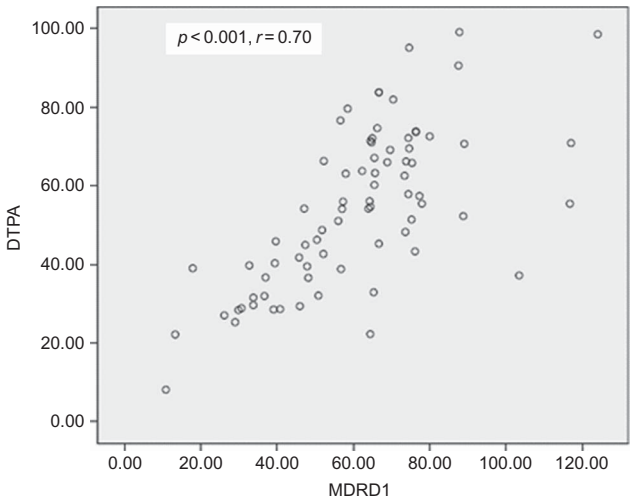

Figure 1. Correlation between ^{99m}Tc-DTPA and MDRD1.
Note: ^{99m}Tc-DTPA, technetium-99m diethylenetriaminepentaacetic acid; MDRD1, modification of diet in renal disease 1.

In the Spearman's nonparametrical correlation analysis of the GFR values measured with ^{99m}Tc-DTPA, there was a statistically significant correlation with the results of all other methods ($p < 0.001$ for all methods) (Table 3 and Figures 1–3). The most significant correlation was identified with MDRD1 in the entire patient group ($n = 76$) ($r = 0.70$; $p < 0.001$) (Table 3).

- At the same time, the formula methods (CrCl, MDRD1, MDRD2, and CGF) were in correlation among themselves ($p < 0.001$). Especially MDRD1 had the highest correlation with MDRD2 and CGF

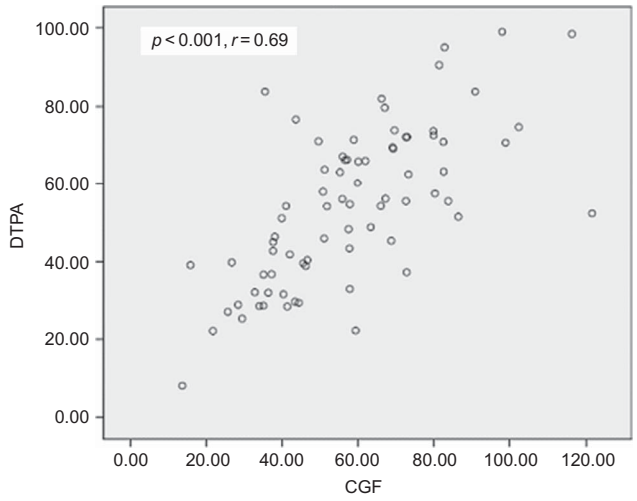

Figure 2. Correlation between ^{99m}Tc-DTPA and CGF.
Note: ^{99m}Tc-DTPA, technetium-99m diethylenetriaminepentaacetic acid; CGF, Cockroft–Gault formula.

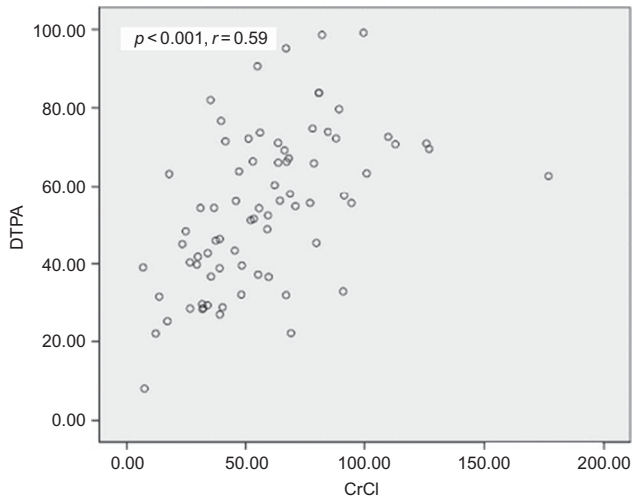

Figure 3. Correlation between ^{99m}Tc-DTPA and CrCl.
Note: ^{99m}Tc-DTPA, technetium-99m diethylenetriaminepentaacetic acid; CrCl, creatinine clearance.

($r = 0.97$ and $r = 0.85$, respectively; $p < 0.001$). The weakest correlation was with CrCl (Table 3).

When the correlation of other methods with ^{99m}Tc-DTPA method was analyzed with emphasis on the subgroup characteristics of the patients:

- Gender difference did not create a significant difference in the correlation between GFR measured by ^{99m}Tc-DTPA and other methods. The most statistically significant correlation was with MDRD1 for both sexes ($r = 0.70$ for women and $r = 0.69$ for men; $p < 0.001$ for both) (Table 4).
- When the age factor was taken into consideration, for patients who were 75 or younger ($n = 53$) the most significant correlation was with CGF ($r = 0.63$; $p < 0.001$), and for patients who were 75 or above ($n = 23$) this was most significant with MDRD1 and MDRD2 ($r = 0.71$; $p < 0.001$ for both) (Table 4).
- When body mass index (BMI) was classified by taking 30 kg/m^2 that is accepted as a threshold for obesity as a reference: for GFR values measured with ^{99m}Tc-DTPA and other methods, patients with a BMI <30 kg/m^2 ($n = 47$) had the highest correlation with MDRD1 ($r = 0.68$; $p < 0.001$). However, in the group with BMI = 30 kg/m^2 and above ($n = 29$), both MDRD1 and MDRD2 formulas had high correlations ($r = 0.71$; $p < 0.001$ for both) (Table 4).
- Based on GFR values calculated with ^{99m}Tc-DTPA that is the reference method, the patients could be grouped into two as those with GFR values of 60 mL/min and above ($n = 31$) and those with values of 60 mL/min and below ($n = 45$), the highest correlation was with MDRD1 for both groups ($r = 0.68$ and $r = 0.72$, respectively; $p < 0.001$ for both) (Table 4).

DISCUSSION

As a result of our study, there was a significant correlation between ^{99m}Tc-DTPA and all other methods; however, the most significant correlation was with MDRD1 (Table 3). At the same time, formula-based methods correlated among themselves. Scr was a common parameter for all GFR formulas, and this was the most important reason behind the high correlation among the results of the formula methods. As the similarity between the other parameters of the formulas increased, the correlation definitely increased.

In another study that had a similar study protocol to ours while using a different isotope in the nuclear method, similar findings were obtained. In this study employing ^{51}Cr-EDTA radioisotope method, CGF, MDRD1, and CrCl formulas were compared in a patient group consisting of 52 patients at an age range of 69–92 years and all three formulas had high correlations with the radioisotopic method ($r = 0.84$, $r = 0.84$, and $r = 0.73$, respectively).[8] In this study, similar to our study, the correlation with CGF and MDRD1 was similar while the correlation with CrCl was of lesser degree.

In accordance with the studies of similar nature, in our study we found a significant correlation between the reference method and the CrCl (Table 3). In this formula, there is no identified coefficient for the difference originating from age and gender. However, using the creatinine in 24 h urine in this formula would decrease the possible errors that would result from the diurnal changes of Scr. This feature was not taken into consideration in other formulas. However, not collecting the urine appropriately and not storing the collected urine under proper storage conditions can result in errors in the calculation of GFR with this formula. That is why

Table 4. The correlation of the methods with ^{99m}Tc-DTPA method based on subgroup characteristics.

	CrCl	MDRD1	MDRD2	CGF
Gender				
Female ($n = 55$)	0.61**	0.70**	0.69**	0.68**
Male ($n = 21$)	0.50**	0.69**	0.65**	0.68**
Age				
75 years or younger ($n = 53$)	0.54**	0.60**	0.57**	0.63**
75 years or older ($n = 23$)	0.42*	0.71**	0.71**	0.59**
BMI				
Below 30 kg/m^2 ($n = 47$)	0.54**	0.68**	0.66**	0.67**
Above 30 kg/m^2 ($n = 29$)	0.61**	0.71**	0.71**	0.69**
GFR				
Below 60mL/min($n = 31$)	0.60**	0.68**	0.67**	0.67**
Above 60 mL/min($n = 45$)	0.53**	0.72**	0.68**	0.66**

Notes: ^{99m}Tc-DTPA, technetium-99m diethylenetriaminepentaacetic acid; CrCl, creatinine clearance; MDRD1, modification of diet in renal disease 1; MDRD2, modification of diet in renal disease 2; CGF, Cockroft–Gault formula; BMI, body mass index; GFR, glomerular filtration rate. $^{**}p < 0.001$; $^{*}p < 0.05$.

we excluded those patients who would not be able to collect the urine properly.

In the MDRD1 formula developed after CGF, coefficients exist for BUN and Alb values, for gender- and race-related changes in addition to Scr. When the difficulty of weighing a patient with unfavorable general health was taken into account, the weight was disregarded in this formula. For patients who lacked Alb and BUN values, MDRD2 formula consisting of race-related variables in addition to Scr, gender, and age was developed.[9]

In a study conducted on 46 elderly patients with a mean age of 80 years, CGF and MDRD1 formulas were compared with ^{51}Cr-EDTA. MDRD1 formula provided a higher GFR value than the reference method while CGF provided a lower estimate.[10] In our study, MDRD1 yielded a higher GFR value than that provided by the reference method (Table 2).

In a study by Itoh,[11] CGF was found to correlate with ^{99m}Tc-DTPA method performed with a camera to calculate GFR while yielding a lower GFR estimate. In a study on individuals with normal kidney function who did not have malnutrition and who were at the ages of 81–96 years, CGF correlated significantly with the radioisotopic method ^{99m}Tc-DTPA ($r = 0.65$); however, it provided a lower GFR estimate than ^{99m}Tc-DTPA (20). The results of our study confirm the above study. However, in our case CGF method yielded a higher GFR estimate (Table 2). This difference might have originated from the differences seen in the characteristics of the study groups and we do not think that this would be of significance in the clinical approach.

Changes seen in the kidney with aging and the incidence of renal diseases do not have a gender preference. In GFR studies in the elderly, a gender-related difference was not found among the methods.[12] Our study also confirmed these results. Both in men and in women, the most significant correlation of ^{99m}Tc-DTPA was identified to be with MDRD1 (Table 4).

Our youngest patient was 65 years old, while the oldest one was 90. In this age interval, the patients in the younger range had higher rates of chronic disease-related complications; age-related changes were mostly seen in patients who were above 80 years of age and who were free from systemic diseases and related complications at a younger age. As the age range of our study was narrower when compared with other studies covering patients from a young–middle-aged population, age-related changes and the effects of systemic diseases created differences of higher degree on the results.

In patients who were 75 years or younger in our study ($n = 53$), the most significant correlation with ^{99m}Tc-DTPA was seen in CGF. In patients who were 75 and above, such a correlation was identified with MDRD1 and MDRD2 (Table 4).

In a study called GIFA (Gruppo Italiano di Farmacovigilanza nell'Anziano) comparing the GFR methods CGF and MDRD in the elderly, as age advanced, the difference between the results of the two formulas increased while the correlation got weaker.[13] As this study did not have a reference method as was the case in our study, it was controversial whether this age-dependent difference was due to the reflection of physiological changes in the elderly or the formula-related features.

In a study covering 61 patients (29 women and 32 men) above the age of 65 years and comparing CGF with MDRD1, in individuals with GFR values of 60 mL/min and below, MDRD1 formula was shown to correlate with the reference method inulin clearance.[14] In our study, both at GFR values of 60 mL/min and below and above, MDRD1 formula had a higher correlation with ^{99m}Tc-DTPA ($r = 0.78$; $p < 0.001$). However, in the patient group with GFR of 60 mL/min and above, MDRD2 and CGF yielded correlations similar to that of MDRD1 (Table 4).

In a study analyzing the influences of age, gender, and BMI variables on GFR, inulin clearance was used

as the reference method and the patients were 65 years or older with GFR levels of 60 mL/min or below. In this study, MDRD1 formula was shown to provide more consistent estimates than CGF. The correlation between the CGF and the reference method decreased as the age and the BMI increased, and it was not affected by the sex. In women, MDRD1-provided GFR estimates that were lower than the reference value and age or BMI did not influence the correlation.[12]

In our study, in patients with BMI = 30 kg/m^2 or below, the highest correlation with the reference method was seen in MDRD1, and for BMI values = 30 kg/m^2 and above MDRD1 and MDRD2 showed similar high correlations (Table 4).

In the calculation of GFR with ^{99m}Tc-DTPA, there was a possible error in obese patients and those with edema. In this technique, there are weight-related correction coefficients. However, in patients with severe edema, there is no such possibility. In such patients, edema should first be treated and ^{99m}Tc-DTPA measurement should be performed afterwards. In our study, we did not have any edematous patients, so the reliability of the radioisotopic technique was not hindered.

In the study that came up with the MDRD formula, 1628 patients with CRD were recruited, most of these patients were middle-aged and the independent productivities of BUN and Alb were proven in this study. That is why MDRD is accepted as an ideal method for middle-aged patients with CRD, and it is yet controversial whether it is ideal for patients at advanced age. CRD is characterized with losses in muscle mass. Patients with similar height, age, and weights might have different body compositions. Especially the muscular mass differs in relation with the severity of the renal failure. In conclusion, MDRD formula developed for CRD patients should be specifically used for this group of patients. Another method that is accepted for GFR measurement with ^{99m}Tc-DTPA is plasma sampling. In a study by Balachandran et al.,[15] a suspicious correlation was identified between 24 h CrCl and GFR measured with ^{99m}Tc-DTPA with multiple plasma sampling, and when inulin clearance was compared with GFR calculated with ^{99m}Tc-DTPA with multiple plasma sampling, this correlation was significant.

In a study by Itoh[11] on 133 patients between the ages of 24 and 84, GFR measurement with ^{99m}Tc-DTPA performed with a camera showed a significant correlation with CGF ($r = 0.79$; $p < 0.001$); this correlation increased with GFR measurements with ^{99m}Tc-DTPA using multiple plasma sampling ($r = 0.82$, $p < 0.001$).

We could have also used multiple plasma-sampled radioisotopic clearance methods for GFR measurements; however, the fact that this test was time-consuming and that it required at least two different blood samples did not correlate with the needs of our group. In conclusion, our aim was to find a practical method to be used in the elderly, although not ideal, it should be as close to the ideal as possible in the estimates of GFR. We therefore decided that the reference technique to be used for comparison should also be less invasive for the elderly and yield results at a short time interval.

Lately GFR measurement with cystatin that is secreted by the nucleated cells and totally catabolized in the tubuli and freely filtrated by the glomeruli entered the agenda. However, this technique is very expensive and the data pertaining to different patient groups are very limited.[16]

Another advantage of the camera method is the possibility to calculate GFR separately for each kidney while providing a total GFR. In pathologies involving a single kidney, this will allow us to eliminate the errors that might be seen as normal GFR for the age range as a result of the normal or high values originating from the healthy kidney. Camera method will make a rough anatomical evaluation at the same time, attracting the attention to gross anatomical pathologies like ectopic localization, horseshoe kidney, and agenesis.[17] In our study, in a patient in whom we planned starting gabapentin for neuropathy, Scr values were normal for a diabetic patient and we realized that the patient was lacking the right kidney due to agenesis.

When we evaluate the results of our study and the results of similar studies, we see that

1. GFR calculation is required in the evaluation of geriatric patients in whom we know that renal reserve is diminished. This is of special importance while decreasing the toxicity of medications with renal clearance and the morbidity and mortality related to renal failure.
2. In elderly with borderline renal failure, there might be the need for replacement due to disease or medications, when the cost of such a treatment is considered, using radioisotopic methods for risky and suspected instances would not be much problematic as concerns the cost. Direct measurement of GFR would reduce the harm in such suspected patients.
3. In the formulas, age, weight, Scr value, and gender are used as parameters. Scr level is affected by the muscle mass. In the elderly, low muscle mass (sarcopenia) is an important clinical problem. On the other hand, by aging, body fat ratio increases and water and muscle ratios decrease. In addition, some diseases like congestive heart failure, chronic renal failure, and cirrhosis lead to edema and are seen much more in the elderly. Therefore, formulas may be more misleading in the elderly.
4. When the need for calculating GFR in all the geriatric population and the increasing population of elderly individuals are taken into consideration, direct GFR measurement in all members of this age group would not be possible because of logistical and cost-related concerns. That is why MDRD and

CGF could be suitable for GFR measurements as they both correlate highly with each other and the ideal method. However, as the correlation is more significant, MDRD1 formula should be used:

- In patients who are 75 years or older.
- In the follow-up of elderly with known renal failure and nephropathy.
- In elderly with a BMI = 30 kg/m^2 or above.
- CGF and MDRD2 formulas can be used if serum Alb and serum urea (Su) measurements are not available.
- The correlation of CrCl with the ideal method is less than the other formulas. Collection of urine for 24 h is difficult in the geriatric population with diminished physical and intellectual capacity and also has a high error ratio. We therefore can think that CrCl loses its validity for the elderly population for the calculation of GFR.

Although performing randomized studies is difficult in the elderly population, we definitely need studies of larger patient size and meta-analyses to validate the findings listed above.

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