scintigraphic technique and makes it difficult to discern improvements in fERPF estimation. Despite this, the complete dynamic scan analysis had a higher correlation with the plasma sample calculation of ERPF ($r = 0.905$) than both the Schlegel ($r = 0.79$) and RUPV ($r = 0.804$) techniques ($p < 0.05$).

CONCLUSION

We have shown that a complete analysis of the dynamic scan data is feasible and provides an accurate estimate of fERPF and ERPF. The method compares favorably with other scintigraphic techniques and is minimally affected by variations in kidney depths, excretion times and plasma tracer concentrations. Because multiplying by an uncertain estimate of plasma volume limits the ultimate potential accuracy of any scintigraphic approach, we suggest that the results be left in their fractional form, fERPF, which would represent ERPF divided by patient plasma volume. In addition to having a distinct technical advantage, this form of ERPF divided by a body fluid volume has also been argued by several authors as having greater physiological value (*5,15*). fERPF already takes into account patient size and thus would not require the traditional clinical procedure of normalization to body surface area (*16*).

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Single-Sample Methods to Measure GFR with Technetium-99m-DTPA

Yi Li, Hyo-Bok Lee and M. Donald Blaufox

Department of Nuclear Medicine, The Albert Einstein College of Medicine, Montefiore Medical Center, Bronx, New York

Many single-sample methods have been suggested to simplify the methodology of glomerular filtration rate (GFR) measurement. The relative accuracy of these competing methods is still not clear for clinical practice. **Methods:** Fifty-four GFR studies with ^{99m}Tc-DTPA were performed on 37 adult patients (serum creatinine 0.8–10 mg/dl). Each study included a UV/P, plasma clearance method (three-sample) and single-sample methods. The single-sample methods used were those of Christensen and Groth (modified by Watson), Constable, Dakubu, Groth and Aasted, Jacobsson, Morgan, Russell and Tauxe. **Results:** When the GFR ≥ 30 ml/min ($n = 26$), all of the single-sample methods were highly correlated with UV/P. The correlation of the single-sample method with the plasma clearance was higher than with UV/P. In this group (GFR ≥ 30 ml/min), the Groth 4-hr sample method had the best value of both absolute difference and percent absolute difference (mean ± s.e. = 11.05 ± 2.51 ml/min and 14.08% ± 2.43%, respectively). Most single-sample methods do not perform well at GFR < 30 ml/min ($n = 28$), and none of them has a good correlation with UV/P or plasma clearance at this level of renal function. However, the Groth and Aasted's 4-hr sample method was the best compared with others (mean ± s.e. = 8.43 ± 1.30 ml/min for absolute difference, and 65.91% ± 16.70% for percent absolute difference). **Conclusion:** Single-sample methods may not correctly predict GFR in advanced renal failure. Groth and Aasted's method with 4-hr plasma sample has both the lowest mean absolute difference and percent absolute difference in both the group with GFR ≥ 30 ml/min and GFR < 30 ml/min. All methods perform acceptably at GFR ≥ 30 ml/min.

Key Words: glomerular filtration rate; technetium-99m-DTPA; plasma clearance; urinary clearance; single-sample method

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Glomerular filtration rate (GFR) can be calculated from the rate of urinary excretion of a constantly infused tracer (classical method) or from the rate of tracer clearance from the plasma after a single intravenous injection. The classic GFR calculation requires blood sampling and often catheterization of the bladder. Clearance also can be calculated using a two-compartment model with multiple blood samples. Classical and multiple blood sample methods for GFR are tedious and time consuming. The single-blood sample method to measure renal function was suggested as early as 1963 by Blaufox (*1*). Since then, one-sample methods were introduced in human study (*2,3*), and there are now a variety of single blood sample methods available. Some investigators used empirical methods comparing the theoretical volume of distribution (V_t) several hours after injection (V_t = dose/plasma activity) with a regression equation (*3–5*). Dakubu (*6*) and Groth and Aasted (*7*) used body surface area (BSA) to correct the plasma activity in an effort to

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For correspondence or reprints contact: M. Donald Blaufox, MD, PhD, Department of Nuclear Medicine, 1695A Eastchester Rd., Bronx, NY 10461.

improve the volume of distribution method. These investigators used a one-compartment model with the assumption that the volume of distribution (V_d) at time 0 (V_d = dose/estimated plasma activity at time 0) is proportional to the body weight or body surface area and that the GFR can be calculated using V_d and the activity in a single plasma sample obtained several hours after injection of tracer with the equations derived from a monoexponential model (*8,9*). In a recent study, Picciotto et al. compared Tauxe's, Constable's and Christensen and Groth's methods using Cr-51 EDTA (*10*). Rehling and Rabol compared Groth and Aasted's, Russell's, Jacobsson's, Tauxe's and Christensen and Groth's methods by using ^{99m}Tc-DTPA (*11*). However, the relative accuracies of these competing methods is still not clear. Since all single-sample methods relate to the volume of distribution of the tracer, the comparison of these methods with plasma clearance is not adequate since they are not independent measures. It is necessary to compare these methods more comprehensively and with a single, widely used renal agent, such as ^{99m}Tc-DTPA, in the same patient to verify their usefulness in clinical practice. This study explored the performance of the more popular single-sample GFR methods by comparing 10 single-sample clearance methods with the UV/P method.

MATERIALS AND METHODS

The study population consisted of patients who underwent routine GFR testing in the Department of Nuclear Medicine at the Jack D. Weiler Hospital of the Albert Einstein College of Medicine. Fifty-four studies (measurements) were performed on 37 patients with a wide range of renal function (serum creatinine 0.8–10 mg/dl). Among these patients, 23 patients had one study, 11 patients had two studies and 3 patients had three studies each. The purpose of repeated studies was for clinical follow-up. The patients included 15 men and 22 women, ages 21–72 yr, body weight 45.9–117 kg, height 116.1–190.5 cm and body surface area (BSA) 1.37–2.44 m^2. The data were derived from analysis of samples obtained during the routine clinical measurement of renal function in patients with suspected renal disease.

All subjects were hydrated with 500 ml of fluid 30 min prior to the test. During the study an intravenous line was placed in one arm with D5W infusion at 125 ml/hr. Two duplicate syringes containing 1 mCi (3.7×10^7 Bq) ^{99m}Tc-DTPA (CIS-US, Bedford, MA) were prepared. One was used for a standard (diluted 1/10,000) and the other for intravenous injection. The patient was asked to void before ^{99m}Tc-DTPA injection. The blood and urine samples were obtained 2, 3 and 4 hr after injection. The urine volume at 2–3 hr and 3–4 hr was measured, and residual urine volume in the bladder was estimated by external counting (*12,13*). The ^{99m}Tc-DTPA urinary clearance was calculated by UV/P. As part of this study, a three-sample method and 10 single-sample methods were used to recalculate the plasma clearances. The UV/P method used clinically is a variation of the standard UV/P method, using a single injection of ^{99m}Tc-DTPA (*14*). The ^{99m}Tc-DTPA plasma clearance was calculated with the three blood samples obtained at 2, 3 and 4 hr (24-hr plasma clearance) using a monoexponential model (Cl = dose × slope/A_0, where A_0 is intercept at time 0) (*15*), and the result was corrected by Brochner-Mortensen's formula to reduce the overestimation of GFR in the monoexponential model (*16*). The blood sampling times of the single-sample methods were selected according to author's recommendations. The details of the methods used are listed in the Appendix (*4,9,17,19*).

The sample time for calculation of GFR for Tauxe's method was selected according to the renal functional status estimated by UV/P. Sampling time was at 120 min when GFR > 100 ml/min, 150 min when GFR 60–100 ml/min and 230 min when GFR < 60 ml/min (*5*). The blood sample activity at 150 min and 230 min was estimated from the 120, 180 and 240 min samples by fitting these three data points to a monoexponential regression equation.

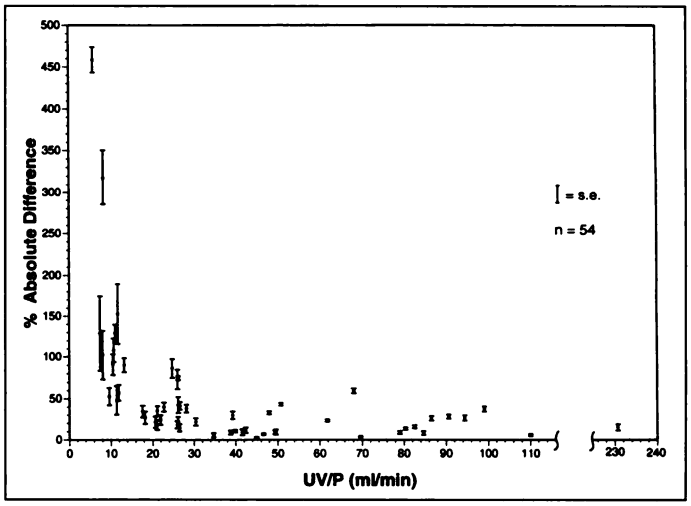

FIGURE 1. Graph of the percent absolute difference of 10 tested single-sample methods versus UV/P (n = 54). Each data point represents the mean percent (± s.e.) of the 10 values in each GFR study. N is the number of GFR studies. For the calculation formula of percent absolute difference, see Results.

Since each one-sample method has an optimal sampling time, any sample that was not taken exactly at the time the author suggested was adjusted by the same regression equation. All analyzed GFR values used were the absolute GFRs of each patient. If the formula yielded a GFR normalized to 1.73 m^2 BSA, the result was converted to absolute GFR. This chart review study was approved by the Montefiore Medical Center Institutional Review Board.

Statistical Analysis

Least squares linear regression and linear correlation analyses were performed using StatView (Abacus Concepts, Inc., Berkeley, CA). Standard deviation and standard error were calculated using Microsoft Excel (Microsoft, Inc., Redmond, WA).

RESULTS

Because the correlation coefficient only tests the relation between two variables, not the difference between them, the correlation coefficient is not sufficient to judge the absolute agreement between the reference method and the tested method (*20*). The absolute differences were computed in order to reveal the agreement between the methods. Our analysis was based on all of the GFR studies (n = 54). Since the differences between the calculated GFR values in each study came from different levels of GFR, the same absolute difference affected the percent difference differently among studies. We normalized each difference between GFR methods to the GFR value of UV/P through computing the percentage of absolute differences between UV/P and single-sample method being tested:

$$\text{The \% absolute difference} = \frac{|\text{Single sample method} - \text{UV/P}|}{\text{UV/P}} \times 100\%$$

The mean percent absolute difference for a given simplified method is its discrepancy from the reference method. Figure 1 shows that the average percent absolute difference of all single plasma methods versus UV/P in individual GFR studies increased greatly when the GFR was <30 ml/min. Therefore, our

TABLE 1
Results of GFR (ml/min) Measured by UV/P, Plasma Clearance and 10 Single-Sample Methods

			A: For GFR ≥ 30 ml/min (n = 26)									
			One-sample method									
ml/min	UV/P	PlCl	Chri (3)	Chri (4)	Cons	Daku	G (3)	G (4)	Jaco	Morg	Russ	Taux
Mean	68.97	73.17	75.50	76.63	77.69	78.51	70.40	71.66	73.55	69.82	71.08	78.40
s.d.	40.13	33.25	42.47	40.35	45.05	50.30	35.75	35.25	44.92	32.56	39.70	44.17
s.e.	7.87	6.52	8.33	7.91	8.84	9.87	7.01	6.91	8.81	6.39	7.79	8.66
Max	230.71	169.45	204.37	200.69	226.20	224.44	171.78	174.31	222.91	143.65	181.54	211.14
Min	30.40	30.45	25.20	27.53	23.75	16.25	25.68	26.61	23.64	27.05	15.46	26.48
			B: For the GFR < 30 ml/min (n = 28)									
			One-sample method									
ml/min	UV/P	PlCl	Chri (3)	Chri (4)	Cons	Daku	G (3)	G (4)	Jaco	Morg	Russ	Taux
Mean	17.84	24.30	22.58	23.32	23.13	12.13	23.11	22.37	15.31	27.04	14.38	24.76
s.d.	7.49	8.75	13.08	10.82	12.47	18.59	12.49	10.70	15.11	8.89	15.45	8.67
s.e.	1.41	1.65	2.47	2.05	2.36	3.51	2.36	2.02	2.85	1.68	2.92	1.64
Max	28.15	43.34	47.94	45.88	48.66	45.95	46.97	44.25	42.13	46.27	44.95	44.85
Min	5.82	10.18	−8.77	−2.43	3.47	−35.10	−7.16	−3.51	−24.27	13.99	−10.87	10.07

PlCl = 2- to 4-hr plasma clearance method (3 plasma sample method), Chri (3) = Christensen and Groth's method modified by Watson with 3-hr plasma sample, Chri (4) = Christensen and Groth's method modified by Watson with 4-hr plasma sample, Cons = Constable's method, Daku = Dakubu's method, G (3) = Groth and Aasted's method with 3-hr plasma sample, G (4) = Groth and Aasted's method with 4-hr plasma sample, Jaco = Jacobsson's method, Morg = Morgan's method, Russ = Russell's method and Taux = Tauxe's method.

GFR data were divided into two groups: GFR ≥ 30 ml/min (n = 26) and GFR < 30 ml/min (n = 28) for further analysis.

A summary of the results of the clearance determinations for UV/P, three-sample ^{99m}Tc-DTPA plasma clearance and the single-sample methods is presented in Table 1A for the GFR ≥ 30 (n = 26) ml/min and Table 1B for the GFR < 30 ml/min (n = 28).

The UV/P method was used as a reference to compare all single-sample methods by linear regression analysis. The correlation of single-sample methods with UV/P and ^{99m}Tc-DTPA plasma clearance in the GFR ≥ 30 ml/min (n = 26) is presented in Table 2A and for the GFR < 30 ml/min (n = 28) in Table 2B.

As shown in Table 2A, when the GFR ≥ 30 ml/min all of the single plasma sample methods were highly correlated with UV/P. The correlation of the single-sample method with the 2- to 4-hr plasma clearance was higher than with UV/P, as expected. Constable's method showed the highest correlation, r = 0.94, with UV/P, whereas Groth and Aasted's method with a 4-hr blood sample showed the lowest standard error (s.e. = 15.24 ml/min) compared to other single plasma sample methods. The lowest correlation with UV/P was Morgan's method (r = 0.85), and Dakubu's method had the highest standard error (s.e. = 21.03 ml/min) when correlated with UV/P. Table 2B shows that the correlations of all single-sample methods with UV/P or 2- to 4-hr plasma clearance were dramatically reduced when GFR < 30 ml/min. None of them has a good correlation, although the correlations with 2- to 4-hr plasma clearance are still better than with UV/P.

The mean absolute difference and the mean percent absolute differences between UV/P and the single-sample methods are shown in Table 3A for the GFR ≥ 30 ml/min (n = 26). Groth and Aasted's method with a 4-hr plasma sample had the lowest value of both indices in this group (mean ± s.e. = 11.05 ± 2.51

TABLE 2
Correlation of Single-Sample Methods with UV/P and Technetium-99m-DTPA Plasma Clearance

		A: For the GFR ≥ 30 ml/min (n = 26)									
		Chri (3)	Chri (4)	Cons	Daku	G (3)	G (4)	Jaco	Morg	Russ	Taux
UV/P	r	0.9224	0.9187	0.9423	0.9123	0.9056	0.9059	0.9378	0.8470	0.9004	0.9147
	s.e. (ml/min)	16.74	16.27	15.39	21.03	15.47	15.24	15.91	17.67	17.63	18.22
PlCl	r	0.9959	0.9971	0.9923	0.9953	0.9960	0.9982	0.9876	0.9862	0.9940	0.9967
	s.e. (ml/min)	3.91	3.13	5.70	5.00	3.28	2.13	7.20	5.51	4.43	3.67
		B: For the GFR < 30 ml/min (n = 28)									
		Chri (3)	Chri (4)	Cons	Daku	G (3)	G (4)	Jaco	Morg	Russ	Taux
UV/P	r	0.2835	0.4327	0.1723	0.3032	0.2800	0.4327	0.5142	0.1791	0.1632	0.3338
	s.e. (ml/min)	12.78	9.94	12.52	18.05	12.22	9.83	13.20	8.91	15.54	8.32
PlCl	r	0.6088	0.7616	0.5065	0.6163	0.6065	0.7605	0.6818	0.5045	0.5037	0.6840
	s.e. (ml/min)	10.57	7.15	10.96	14.92	10.12	7.08	11.26	7.82	13.61	6.45

r = correlation coefficient. See Table 1 for other abbreviations.

TABLE 3
Mean Absolute Difference and Mean % Absolute Differences between UV/P and Single-Sample Method

A: For the GFR ≥ 30 ml/min (n = 26)										
Absolute difference (ml/min)	Chri (3)	Chri (4)	Cons	Daku	G (3)	G(4)	Jaco	Morg	Russ	Taux
Mean	12.73	12.58	12.08	17.96	11.21	11.05	12.25	11.79	13.32	13.52
s.d.	11.84	12.40	12.40	14.44	12.46	12.80	10.41	17.36	11.50	14.58
s.e.	2.32	2.43	2.43	2.83	2.44	2.51	2.04	3.40	2.25	2.86
% Absolute difference										
Mean	18.18	16.96	17.81	28.14	15.19	14.08	19.09	14.28	20.34	18.07
s.d.	15.04	15.31	17.09	18.97	11.78	12.37	14.45	13.29	15.09	17.59
s.e.	2.95	3.00	3.35	3.72	2.31	2.43	2.83	2.61	2.96	3.45
B: For the GFR < 30 ml/min (n = 28)										
Absolute difference (ml/min)	Chri (3)	Chri (4)	Cons	Daku	G (3)	G (4)	Jaco	Morg	Russ	Taux
Mean	10.70	9.02	11.83	13.82	10.57	8.43	9.52	11.37	12.91	9.31
s.d.	8.57	6.94	7.82	12.15	8.37	6.85	8.82	7.92	9.65	6.73
s.e.	1.62	1.31	1.48	2.30	1.58	1.30	1.67	1.50	1.82	1.27
% Absolute difference										
Mean	83.43	70.14	90.68	105.80	82.56	65.91	79.25	95.51	87.88	76.80
s.d.	110.85	91.57	111.11	119.32	110.65	88.39	108.37	115.87	97.62	96.60
s.e.	20.95	17.30	21.00	22.55	20.91	16.70	20.48	21.90	18.45	18.26

See Table 1 for key to abbreviations.

ml/min for absolute difference and 14.08% ± 2.43% for percent absolute difference).

The mean absolute difference and the mean percent absolute difference between UV/P and the single-sample method for the GFR < 30 ml/min (n = 28) are shown in Table 3B. Most methods do not perform well at GFR < 30 ml/min. However, Groth and Aasted's method with a 4-hr plasma sample also had the lowest value compared with others (mean ± s.e. = 8.43 ± 1.30 ml/min for absolute difference and 65.91% ± 16.70% for percent absolute difference).

DISCUSSION

Twenty-four-hour creatinine clearance is a widely used clinical method in GFR evaluation. However, its major drawback is the need for compliance and the overestimation of GFR in renal failure that reduces its accuracy and reliability (*21*). A large number of radioactive agents have been developed for estimating GFR (*22*). Among them, ^{99m}Tc-DTPA is the most widely used agent in the U.S. Some studies suggest that there is no significant difference in plasma clearance between ^{99m}Tc-DTPA and ^{51}Cr-EDTA (*23,24*), and the clearance of ^{99m}Tc-DTPA and inulin is similar (*24*). Since the quality of the DTPA preparations differs (*23,25*), and ^{51}Cr-EDTA and ^{125}I or ^{131}I diatrizoate have less protein binding than ^{99m}Tc-DTPA, the single-sample GFR formulas established for these agents should be verified before they are used with ^{99m}Tc-DTPA.

Single-sample methods can be divided into two major categories, empirical and compartmental. The empirical method uses the theoretical volume of distribution at a given time (V_t) (*3*). The optimal sampling time to determine volume of distribution depends on the level of renal function (*5*). Large variations in an individual's volumes of distribution obviously will reduce the accuracy of GFR estimation. Efforts have been made to correct the individual variations in the estimation extracellular volume (ECV) that relate to V_d. In our study, the results suggest that Groth and Aasted's method provides a better estimation of GFR than other single plasma sample methods. Jacobsson attempted to use a one-compartment model by calculating V_d from body weight, but this does not provide increased accuracy. Christensen and Groth introduced another one-compartment method by estimating ECV from BSA. Its calculation is iterative and, therefore, a computer program is needed to solve this laborious problem. This method has been modified and simplified by Watson (*19*) and was used in this investigation. The original method of Christensen and Groth is not included in our current study. From the results of Rehling and Rabol (*11*), the accuracy of this iterative method was somewhat lower than the Groth and Aasted method with ^{99m}Tc-DTPA. They compared five single-sample methods. In this study, Groth and Aasted's method also showed a slightly better result than Christensen and Groth's method. Russell's method originally used ultrafiltered plasma for correcting protein binding. Whole plasma was used in this study. A comparison of single plasma methods using protein-free plasma is needed to verify the relative accuracy of Russell's method. However, clinically it is easier to use a method in which the dose not require ultrafiltration. Protein binding varies with the preparation used, and the preparation in this study has low

protein binding that seems to make whole plasma acceptable for most methods.

Most single-sample GFR methods will be more reliable when they are used for those patients with GFR ≥ 30 ml/min. All single-sample methods yielded a small percent absolute difference at GFR ≥ 30 ml/min, but in patients in whom the GFR < 30 ml/min, the percent absolute difference is much higher.

The possible factors which affect the accuracy and precision of clearance measurement in the GFR range < 30 ml/min include: (a) extrarenal clearance in patients with GFR < 30 ml/min because of a prolonged time of reaching equilibrium (*26*); (b) when the value of GFR is small (i.e., a GFR < 30 ml/min), a small absolute difference causes a larger relative error (percent difference); (c) the arterio-venous concentration difference of DTPA in the single-injection method can underestimate GFR because of the changes in forearm blood flow as pointed out by Rehling. This influence is smaller when renal function is reduced (*27*), affecting the accuracy of formulas derived for a wide range of renal function.

CONCLUSION

Groth and Aasted's method with a 4-hr plasma sample has the lowest means of both absolute difference and percent absolute difference in patients with GFR ≥ 30 ml/min as well as those with GFR < 30 ml/min, but it should be noted that the difference between Groth and Aasted's method and other methods was not statistically significant. Christensen and Groth's method modified by Watson with a 4-hr plasma sample appears slightly less accurate than Groth and Aasted's method with a 4-hr plasma sample. But it has the advantage that calculation of the result is easier because its formula corrects for sampling time, avoiding the requirement that sampling time has to be exactly 4 hr after injection.

APPENDIX

Formulas for Single Plasma Sample GFR Measurement

Christensen and Groth's Method Modified by Watson (9,19):

$$\text{GFR (ml/min)} = [-b + (b^2 - 4ac)^{1/2}]/2a$$

where $a = t \times (0.0000017 \times t - 0.0012)$
$b = t \times (-0.000775 \times t + 1.31)$
$c = ECV \times \ln (ECV/V_t)$
ECV = extracellular volume (ml) = $8116.6 \times BSA - 28.2$
V_t = tracer apparent volume (ml) of distribution at time t
t = sampling time (min)
BSA = Body surface area (m^2).

For 3-hr plasma sample:

$$a = -0.1609;\ b = 210.7;\ c = ECV \times \ln (ECV/V_{180})$$

where V_{180} = tracer apparent volume (ml) of distribution at 180 min.

For 4-hr plasma sample:

$$a = -0.1901;\ b = 269.8;\ c = ECV \times \ln (ECV/V_{240}),$$

where V_{240} = tracer apparent volume (ml) of distribution at 240 min.

Constable's Method (4):

$$\text{GFR (ml/min)} = 24.5 \times (V_3 - 6.2)^{1/2} - 67,$$

where V_3 = tracer apparent volume (liters) of distribution at 3 hr.

Dakubu's Method (6):

$$\text{GFR (ml/min/1.73 m}^2) = 95.33 \times \ln (V_3') - 270.99$$

where V_3' = tracer apparent volume (liters) of distribution per 1.73 m^2 at 3 hr.

Groth and Aasted's Method (7):

$$\text{GFR (ml/min/1.73 m}^2) = (0.213 \times T - 104) \times \ln (Y_t \times A/Q_0) + 1.88 \times T - 928,$$

where T = sampling time (min); T = 180 for 3-hr method; T = 240 for 4-hr method
Y_t = the activity counts of 180-min or 240-min plasma sample (CPM/ml)
A = body surface area (m^2)
Q_0 = Total injected dose counts (cpm).

Jacobsson's Method (8):

$$\text{GFR (ml/min)} = \frac{\ln (Q_0/(V' \times C_t))}{t/V' + 0.0016},$$

where t = sampling time (240 min)
C_t = Plasma activity (CPM/ml) at time t
Q_0 = Total injected dose counts (CPM)
V′ = Calculated volume of distribution (ml) = 24.6% × body weight (g).

Morgan's Method (17):

$$\text{GFR (ml/min)} = 23.92 + 2.78 \times V_{180} - 0.0111 \times (V_{180})^2,$$

where V_{180} = tracer apparent volume (liters) of distribution at 180 min.

Russell's Method (18):

$$\text{GFR (ml/min)} = A \times \ln (D/P) + B,$$

where $A = -0.278 \times T + 119.1 + 2450/T$
$B = 2.886 \times T - 1222.9 - 16820/T$
D = total injected dose counts (CPM)
P = plasma activity (CPM/ml)
T = sampling time (180 min).

Tauxe's Method (5):

$$\text{GFR (ml/min)} = Gmax\ [1 - e^{-a(Vt\ -\ Vlag)}],$$

where $V_t = DI/C_t$ (tracer apparent volume (ml) of distribution)
DI = total injected dose counts (CPM)
C_t = plasma activity (cpm/ml) at the time of sampling.

For GFR	Sampling time	Gmax	a	Vlag
>100 ml/min	120 min	361.8	0.0124	10.1
60–100 ml/min	150 min	208.8	0.0192	11.0
<60 ml/min	230 min	141.7	0.0178	11.0

a = alpha = the rate constant.
Gmax = the theoretical asymptotic maximum value of GFR.
Vlag = intercept of the fitted curve on the abscissa.
e = the base of the natural logarithm.

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MAG3 Renogram Deconvolution in Kidney Transplantation: Utility of the Measurement of Initial Tracer Uptake

María-Teresa Bajén, Rafael Puchal, Angel González, José-María Grinyó, Alberto Castelao, Jaime Mora and José Martin-Comin

Department of Nuclear Medicine, Lab of Biophysics and Bioengineering; and Department of Nephrology, Bellvitge University Hospital, L'Hospitalet de Llobregat, Barcelona, Spain

The study of renal retention function by deconvolution analysis of renographic curves is useful to calculate quantitative parameters in renal studies. The aim of the work is to evaluate the usefulness of ^{99m}Tc-MAG3 renogram deconvolution in renal function monitoring of kidney graft recipients. **Methods:** Forty-three kidney grafts and 112 renograms were studied: 41 were diagnosed as functioning graft, 35 as acute tubular necrosis, 24 as acute rejection, 8 as obstruction and 4 as cyclosporin toxicity. The parameters calculated were mean transit time (MTT), time at 20% of renal retention function (T20) and initial uptake (IU). **Results:** MTT and T20 were significantly longer in obstructives than in functioning grafts ($p < 0.001$). Initial uptake was significantly lower in acute tubular necrosis (ATN) and acute rejection ($p < 0.001$) and in obstructives ($p < 0.05$) than in functioning grafts. The joint evaluation of MTT and IU allowed to diagnose cases with graft function severely impaired. **Conclusion:** Initial uptake is useful in evaluating post-transplantation complications and in combination with MTT and T20 reflects renal dysfunction severity.

Key Words: renal transplantation; technetium-99m-MAG3; deconvolution analysis

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Dynamic renal scintigraphy is routinely applied in most nuclear medicine departments to study renal transplants (*1*). The technique is accurate for the functional evaluation of kidney function and is a useful tool for clinicians in the postoperative follow-up of transplanted patients (*2,3*). Since its introduction in 1987, the use of mercapto-acetyl-triglycine (MAG-3) labeled with ^{99m}Tc has increased and progressively replaced ^{131}I-OIH and ^{99m}Tc-DTPA as tracer for renal functional studies.

Several different parameters are used to follow the kidney's progress. This fact suggests that there is not one that is ideal. Nevertheless, it can be agreed that to determine the intrarenal kinetics and to calculate quantitative parameters, the study of the renal retention function (RRF) is useful. The RRF is calculated by deconvolution analysis of the renographic curves (*4*). There is little experience in deconvolution in renal transplanted patients (*5–7*) and even less with ^{99m}Tc-MAG3 (*8*).

In 1992, we developed a deconvolution method for MAG3 renography, for which initial results in normal volunteers and functioning kidney grafts were promising (*9*). The aim of this work was to study the usefulness of that deconvolution method with ^{99m}Tc-MAG3 in kidney graft monitoring. We evaluated the RRF derived parameters: initial uptake (IU) and two transit times of the tracer: mean transit time (MTT) and time at 20% of the RRF (T20). We analyzed if they reflect the graft function accurately and also compared the RRF with the effective renal

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For correspondence or reprints contact: José Martin-Comin, MD, Deptartment of Nuclear Medicine, Hospital Universitari de Bellvitge, Feixa Llarga s/n. 08907 L'Hospitalet de Llobregat, Barcelona, Spain.