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Estimation of ^{99m}Tc-MAG3 clearance by single-sample methods and camera-based methods

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We compared single-sample methods, proposed by Russell et al. and Bubeck et al., and camera-based methods in calculating ^{99m}Tc-MAG3 clearance, and determined camera-based methods that provide estimates comparable to those measured by the Russell method. Twenty-one patients underwent ^{99m}Tc-MAG3 renal scintigraphy, and clearance was measured by the Russell method and Bubeck method. Various renogram parameters were determined based on the slope of the renogram and area under the renogram, and correlated with the clearance measured by the Russell method. Camera-based clearance was calculated with the obtained regression equations and with equations determined previously using the Bubeck method as a standard. The Bubeck method provided lower measures than the Russell method in high renal function. Clearance measured by the Russell method was well correlated with renogram parameters, and clearance calculated with the obtained regression equation was comparable to that measured by the Russell method. When camera-based clearance was predicted with the previous equation, it was lower than the result obtained by the Russell method in high function. In conclusion, there are systematic differences in ^{99m}Tc-MAG3 clearance calculated by different methods. The camera-based methods obtained in this study appear to facilitate comparison of results obtained by the Russell method and camera-based method.

Key words: ^{99m}Tc-MAG3, renal function, camera-based method, single-sample method

INTRODUCTION

CAMERA-BASED METHODS without blood sampling are widely used to assess renal function from dynamic renal scintigraphy. Various camera-based methods have been reported to calculate the clearance of ^{99m}Tc-mercaptoacetyltriglycine (^{99m}Tc-MAG3).[1–7] Although less precise than methods with blood sampling, they are convenient and allow the estimation of relative renal function in addition to absolute function.

We have examined the relation between various renogram parameters and ^{99m}Tc-MAG3 clearance, and described camera-based methods to estimate ^{99m}Tc-MAG3 clearance based on the slope of the early part of the renogram (slope method) or the area under the renogram (area method).[7] In the study the single-sample method described by Bubeck et al.[8] was used as a standard to measure ^{99m}Tc-MAG3 clearance. The single-sample method of Russell et al.[9] is another well-established technique to measure ^{99m}Tc-MAG3 clearance. They both are considered to be sufficiently reliable, however, discrepancy in estimated clearance has been shown.[9] In the present study we correlated renogram parameters with ^{99m}Tc-MAG3 clearance measured by the Russell method to modify our camera-based methods, and compared clearance values calculated by single-sample methods and camera-based methods. The principal aim of this study was to determine camera-based methods that give estimates comparable to those obtained by the single-sample method of Russell et al.

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MATERIALS AND METHODS

Subjects

The patient data used in the present study were the same as those used in our previous study.[7] Twenty-one patients (8 men and 13 women; age range 21–87 y, mean 58.0 ± 20.2 y) who underwent renal scintigraphy with ^{99m}Tc-MAG3 to evaluate various renal disorders were studied. One patient had a single kidney; the others had two kidneys.

Imaging Procedures

Thirty minutes after the oral intake of 250 m*l* water, ^{99m}Tc-MAG3 (250 MBq) was administered intravenously with the patient in the supine position, and dynamic data were recorded in the posterior view for 30 min. Eighty 3-sec frames were acquired in a 128 × 128 matrix with a 20% energy window centered at 140 keV, followed by the collection of 52 30-sec frames. A gamma camera (Vertex, ADAC Laboratories, Milpitas, CA) equipped with a low-energy general-purpose collimator interfaced to a dedicated workstation was used. The injection syringe was also imaged before and after injection to estimate the injected dose with the same camera system.

Data Analysis

Venous blood samples were obtained from the arm contralateral to the injection site 40 min after tracer injection, and plasma activity was assessed with a well counter. ^{99m}Tc-MAG3 clearance was measured by the single-sample method of Russell et al., which was used as a standard in this study. Clearance was also calculated by the single-sample method of Bubeck et al. and compared with the result obtained by the Russell method. In this study, all estimates of clearance were normalized for body surface area computed with the equation of Haycock et al.[10]

Renogram parameters, slope index for the slope method and percent renal uptake for the area method, were obtained as described in the previous paper.[7] Briefly, regions of interest (ROIs) were drawn for the kidneys, subrenal background areas, and perirenal background areas to generate background-subtracted renograms. The slope of the background-subtracted renogram was determined by linear regression analysis 0.5–1.5 min and 0.5–2 min after tracer arrival in the kidney. The depth of each kidney (D, cm) was calculated with the equations of Taylor et al.[11] for attenuation correction, and the attenuation factor was determined as $e^{-0.12 \times D}$. The slope index at T1–T2 min (SI_{T1-T2}) was calculated with the following equation:

$$SI_{T1-T2} = 1{,}000{,}000 \times (rS_{T1-T2}/AFr + rS_{T1-T2}/AFl)/Ci$$

where rS_{T1-T2} and lS_{T1-T2} are slopes calculated from the right and left renograms at T1–T2 min (cps/sec), respectively, AFr and AFl are attenuation factors for the right and left kidneys, respectively, and Ci is injected count (cpm). Renal accumulation at 1–2 min and 1–2.5 min was calculated as area under the background-subtracted renogram. The percent renal uptake at T1–T2 min (RU_{T1-T2}) was computed as follows:

$$RU_{T1-T2} = 100 \times (rCa_{T1-T2}/AFr + lCa_{T1-T2}/AFl)/Ci$$

where rCa_{T1-T2} and lCa_{T1-T2} are renal accumulation at T1–T2 min for the right and left sides (cpm), respectively.

Linear regression was performed for ^{99m}Tc-MAG3 clearance measured by the Russell method plotted against the slope index or percent renal uptake, and equations to calculate clearance from renogram parameters were obtained. Clearance was predicted with each equation, and the residual, absolute difference between the predicted clearance and clearance measured by the Russell method, was calculated as a marker of error in prediction by the camera-based method.

Clearance measured by the Bubeck method was compared with the renogram parameters in our previous study,[7] and the equation to convert the slope index at 0.5–2 min using the subrenal background to ^{99m}Tc-MAG3 clearance (CL) was determined as follows:

$$CL\ (ml/min/1.73\ m^2) = 12.725 \times SI_{0.5-2} + 6.24.$$

Clearance predicted with this equation was compared with that measured by the Russell method.

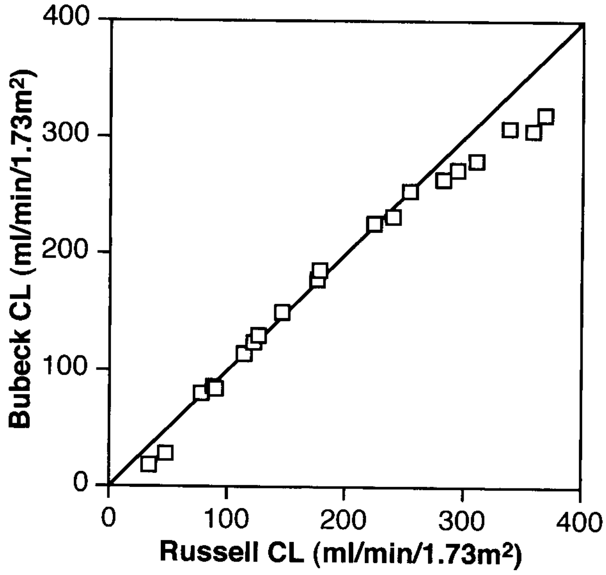

Fig. 1 ^{99m}Tc-MAG3 clearance (CL) measured by the Russell method and Bubeck method. Solid line represents the identical line.

RESULTS

^{99m}Tc-MAG3 clearance measured by the Russell method was 194.2 ± 104.4 m*l*/min/1.73 m^2, ranging from 32.7 to 367.0 m*l*/min/1.73 m^2. Clearance measured by the Bubeck method was 183.3 ± 94.1 m*l*/min/1.73 m^2, ranging from 17.5 to 320.0 m*l*/min/1.73 m^2. Discrepancy was observed

Table 1 Relation between ^{99m}Tc-MAG3 clearance and renogram parameter

Parameter	Time (min)	Background	Regression Equation				Residual	
			Slope	Y-intercept	r	SEE	Mean	SD
RU	1–2	peri	13.017	9.89	0.925	40.7	31.3	23.2
RU	1–2.5	peri	12.169	8.28	0.926	40.4	31.1	23.0
RU	1–2	sub	12.101	−4.25	0.917	42.7	33.4	23.6
RU	1–2.5	sub	11.415	−4.43	0.919	42.4	33.2	23.4
SI	0.5–1.5	peri	11.862	−10.90	0.960	29.8	21.3	19.3
SI	0.5–2	peri	13.003	−13.62	0.956	31.5	24.8	17.2
SI	0.5–1.5	sub	12.801	4.44	0.973	24.7	19.1	14.0
SI	0.5–2	sub	14.065	−1.52	0.968	26.7	21.3	14.3

time = time period for analysis, RU = percent renal uptake, SI = slope index, peri = perirenal background, sub = subrenal background

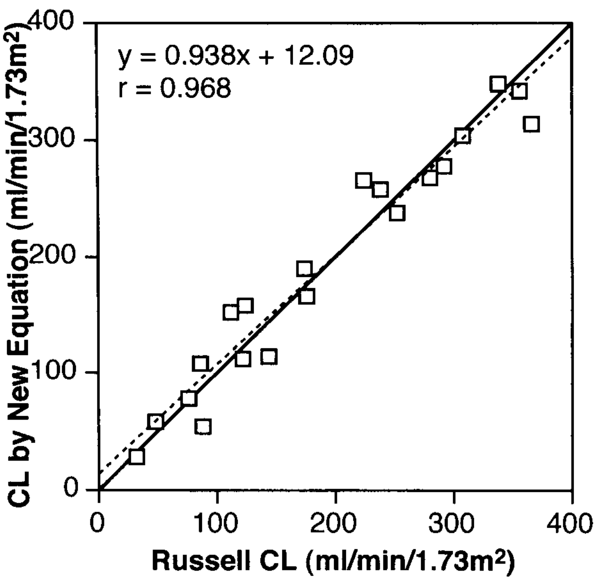

Fig. 2 ^{99m}Tc-MAG3 clearance (CL) measured by the Russell method and predicted by a camera-based method. In the camera-based method, slope index at 0.5–2 min using the subrenal background was converted to clearance with the equation determined in this study. Solid and broken lines represent the identical line and regression line, respectively.

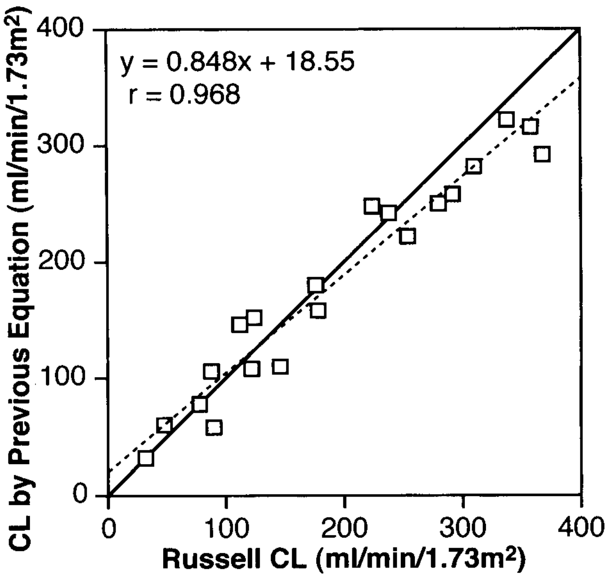

Fig. 3 ^{99m}Tc-MAG3 clearance (CL) measured by the Russell method and predicted by a camera-based method. In the camera-based method, slope index at 0.5–2 min using the subrenal background was converted to clearance with the equation determined in the previous study using the Bubeck method as a standard. Solid and broken lines represent the identical line and regression line, respectively.

at a high level of clearance, and the Bubeck method tended to provide lower measures than the Russell method (Fig. 1).

Clearance measured by the Russell method was well correlated with slope indices and percent renal uptakes (Table 1). Correlation coefficients were higher for slope indices (0.956–0.973) than for percent renal uptakes (0.917–0.926). The residual for the percent renal uptake at 1–2.5 min using the perirenal background, which was the smallest among those for the area methods, was significantly larger than that for the slope index at 0.5–1.5 or 0.5–2 min using the subrenal background ($p < 0.01$ and $p < 0.05$, respectively, paired t-test). Clearance predicted with the obtained regression equation and slope index at 0.5–2 min using the subrenal background was closely correlated with the clearance measured by the Russell method, and the regression line was close to the identical line (Fig. 2). When clearance was predicted with the equation determined using the Bubeck method as a standard, the predicted value was systematically lower than clearance measured by the Russell method in patients with high renal function (Fig. 3).

DISCUSSION

A single-sample method is accepted as a method of choice for the estimation of ^{99m}Tc-MAG3 clearance, if feasible.[12] Bubeck et al. and Russell et al. described single-sample methods applicable to both children and adults.

Although both methods appear reliable, it has been found that the Bubeck method gives systematically lower results than the Russell method at a high level of renal function,[9] which is consistent with the observation in the present study. Bubeck et al. used a continuous infusion technique as a reference in developing their single-sample method, while Russell et al. used a single-injection, multiple-sample technique. The difference in calculated clearance appears to be attributable to the difference in the reference method used for development.

A camera-based method is another choice for the estimation of clearance in clinical practice, and is more convenient than a single-sample method. We have determined camera-based methods using the Bubeck method as a standard.[7] In the present study we examined the relation between renogram parameters and clearance measured by the Russell method, and determined the equations to compute clearance from renogram parameters. Correlation coefficients between slope indices and measured clearance were higher than those between percent renal uptakes and measured clearance, which is consistent with the results of comparison of renogram parameters with clearance measured by the Bubeck method. The slope method is indicated to be more precise than the area method in calculating ^{99m}Tc-MAG3 clearance. However, data from a relatively small number of patients were analyzed in this study, and further validation is needed.

Because our previous equation was determined using the Bubeck method as a standard, it is natural that clearance calculated with the equation was lower than clearance measured by the Russell method in patients with high renal function. Such systematic difference was resolved with the equation determined in this study. A single-sample method provides higher accuracy than a camera-based method. In clinical practice, one may choose a single-sample method when it is feasible, and may use a camera-based method when it is better to avoid blood sampling or calibration data used to compare the plasma concentration with the injected dose are not available. Although direct comparison of values estimated by different methods is not ideal, it may be justified in a clinical setting.[13] Eliminating systematic difference in estimates is expected to facilitate interpretation of the results. The camera-based methods determined using the Russell method as a standard appear to provide estimates that are relatively suitable to comparison with results obtained by the Russell method. The use of the camera-based methods presented in the previous study[7] would be recommendable when comparison with estimates obtained by the Bubeck method is required.

CONCLUSION

There are systematic differences in ^{99m}Tc-MAG3 clearance estimated by different methods. The use of the camera-based method obtained in this study eliminates systematic difference between values calculated by the Russell method and the camera-based method, and may be preferable when calculated clearance should be compared with clearance measured by the Russell method.

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