

Validity of ^{99m}Tc -DMSA renal uptake by planar posterior-view method in children

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Renal uptake of ^{99m}Tc -DMSA has been quantified by various methods. The aim of this study is to obtain a normal value for ^{99m}Tc -DMSA renal uptake calculated by the posterior view method and age variation, and to assess its clinical validity. Scintigrams of 238 children (0–12 years) with ^{99m}Tc -DMSA were reviewed. All the children had a clinical history of primary vesicoureteral reflux and/or neurogenic bladder, ureteral or urethral anomalies. Their kidneys were divided into two groups, “normal” and “abnormal” according to their scintigraphic findings and split renal functions. Percent renal uptake per injected dose (% RU) was quantitated from planar images at 2 hours after injection of an age-adjusted dose (26–95 MBq) of ^{99m}Tc -DMSA. Calculated total % RU, individual % RU of the right and left kidneys (mean \pm sd) in patients with normal kidneys were $40.7 \pm 5.0\%$, $20.2 \pm 3.0\%$, $20.4 \pm 2.7\%$, respectively. There was no significant correlation between % RU and age ($r = 0.231$). Longitudinal variation in the % RU in 9 patients ranged from 1.2% to 18%. Our conventional method for quantifying % RU is simple, practical and feasible in routine clinical practice, especially for children under follow up.

Key words: ^{99m}Tc -DMSA, % renal uptake, normal value, age-dependency

INTRODUCTION

THE QUANTIFICATION of renal uptake with radionuclide studies is a simple and non-invasive way to assess the renal function. Renal uptake of ^{99m}Tc -DMSA is considered to express functioning renal mass.^{1–3} It depends on blood flow to the kidneys, glomerular filtration and tubular transport mechanisms. The term “functioning renal mass” does not express a single function but a more complex physiology and radiopharmaceutical behavior. It closely relates to other measurements of renal function, especially effective renal plasma flow,^{4–6} but the precise mechanisms of uptake is unknown⁷ and how it corresponds to clinical situations in each patient remains unclear. Nevertheless % renal uptake (% RU) of ^{99m}Tc -DMSA may be used as an index of renal function and to

see the change in renal function at follow up. A simple method for calculating % RU is desirable in routine practice, especially in children under follow up.

Several methods for quantifying the renal uptake of ^{99m}Tc -DMSA in children have been proposed: by using only the posterior view of planar imaging,⁸ anterior and posterior view planar imaging,^{9,10} and SPECT.¹¹ We previously reported the method for calculating % RU of ^{99m}Tc -DMSA from posterior planar data at 2 hours after injection.¹² It is a simple and practical way to calculate % RU and needs shorter examination time than other methods.

The aim of this study is to obtain normal values by means of our method and its age variation. We also discuss the clinical validity of our method.

PATIENTS AND METHODS

Patients

We reviewed scintigrams with ^{99m}Tc -DMSA in 238 children with VUR and/or ureteral or urethral abnormalities. The age ranged from 0 to 13 years (average 6.2 years). There were 103 girls and 135 boys.

Received April 12, 1999, revision accepted August 9, 1999.

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Imaging

Patients who could not cooperate in the ^{99m}Tc -DMSA study were sedated prior to the study. ^{99m}Tc -DMSA was prepared by adding freshly eluted ^{99m}Tc to a commercially available freeze-dried kit (Daiichi Radioisotope Lab. Co., Tokyo). A single rotating gamma camera (Toshiba GCA602) equipped with a low energy high-resolution parallel-hole collimator was positioned posteriorly with the patient in the supine position. Posterior planar images were taken precisely 2 hours after injection of an age-adjusted dose (26–95 MBq) of ^{99m}Tc -DMSA for a preset time of 5 minutes on a 512×512 matrix. Supplemental posterior oblique images were also obtained. After the completion of the planar study, SPECT projection images were acquired on a 128×128 matrix for 20 seconds at each of the 60 positions over 360 degree rotation. They were reconstructed by means of 5 point pre-smoothing and using a Shepp and Logan digital filter. Conventional coronal images in relation to somatome axis and reoriented coronal images in relation to the visceral axis of the kidney after correction for renal axis rotation were generated.

% RU of ^{99m}Tc -DMSA was calculated from planar posterior image data using the equations previously described¹² (see appendix). For quantitation, physical decay of ^{99m}Tc from the time of injection to the planar study and tissue attenuation of gamma rays from ^{99m}Tc -DMSA in the kidney were corrected mathematically. The linear attenuation coefficient of ^{99m}Tc was set at -0.153 . The renal depth (cm) was estimated from the equation for body weight (kg) and height (cm) previously reported by Itoh and Arakawa¹³: depth of the right kidney = $17.3 \times (\text{weight}/\text{height})^{-0.8099}$, depth of the left kidney = $14.8 \times (\text{weight}/\text{height})^{-0.6997}$.

Selection of Scintigrams

The most recent scintigrams were used for the analysis when the examination was performed on more than one occasion in one patient. Serial % RU from repeated examinations were compared by calculating the coefficients of variation.

Two experienced nuclear physicians reviewed the scintigrams (both planar and SPECT images) and classified the kidneys as "normal" and "abnormal" by consensus. The kidneys were classified as "normal" when they had smooth outlines, no focal loss of cortex, no contractions on both planar and SPECT images and when their split renal functions were in the 45–55% range. Their serum creatinine and blood urea nitrogen were within normal limits.

Statistical Analysis

% RU of ^{99m}Tc -DMSA and patients' age were compared by linear regression.

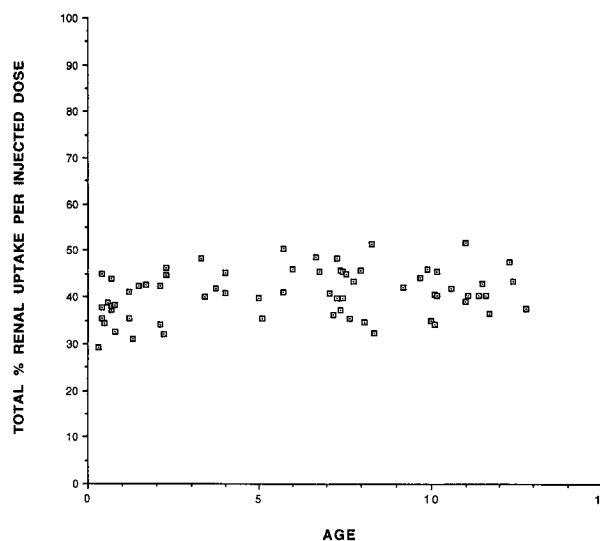


Fig. 1 Relationship between total % RU and age. There is no significant correlation between % RU and age in children with normal kidneys. ($r = 0.231$, N.S.)

RESULTS

Of 238 children reviewed, 68 patients had bilaterally normal kidneys. Total % RU of ^{99m}Tc -DMSA in these 68 patients ranged from 29.0% to 51.7% (mean \pm SD: 40.7 ± 5.0). Right % RU and left % RU ranged from 13.5% to 28.0% (mean \pm SD: 20.2 ± 3.0) and 14.1% to 26.1% (mean \pm SD: 20.4 ± 2.7).

There was no significant correlation between age and total % RU of ^{99m}Tc -DMSA and age ($r = 0.231$, N.S.) (Fig. 1) in the patients with normal kidneys.

Serial % RUs of bilaterally normal kidneys were obtained in 9 patients examined on more than two occasions (3–6 occasions). Their scintigrams were interpreted as normal throughout the series of examinations. The coefficients of variation of the serial % RU ranged from 1.2 to 18.4% (Fig. 2).

DISCUSSION

In order to calculate the renal uptake of ^{99m}Tc -DMSA in children, various non-invasive methods and their normal values have been reported.^{8–11} They are around 50% as shown in Table 1.^{8–11} Our results are a little less than previously reported but they seem to correspond them.

There are several factors which have a significant influence on quantifying renal uptake¹⁴ such as renal depth correction,^{15–18} acquisition timing,^{19,20} size of regions of interest^{21,22} and background correction.^{7,18} We quantified % RU from posterior image data alone 2 hours after injection. It needs a shorter examination time than other methods. Murase et al.¹⁷ investigated % RU of ^{99m}Tc -DMSA calculated by three different methods: the posterior method including the method with renal depth

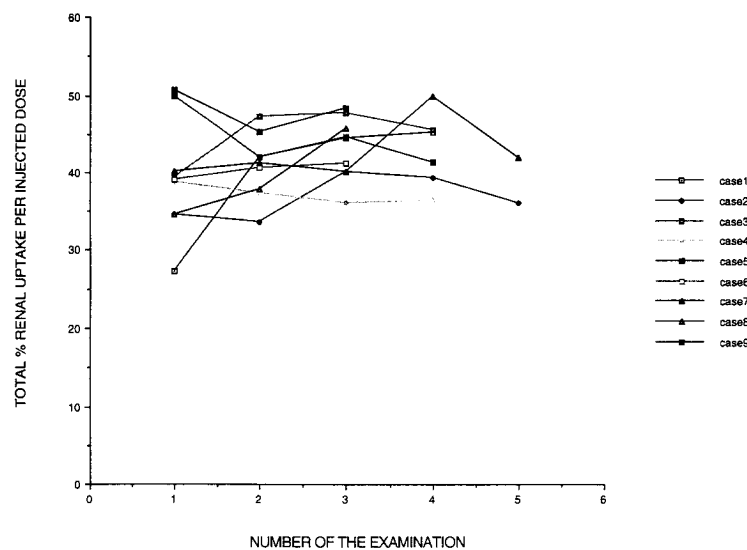


Fig. 2 Longitudinal variation of total % RU in 9 patients. Small variation are shown in most of the patients except cases 1 and 8.

Table 1 Normal values of the absolute renal uptake per injected dose calculated with various methods

Reporter	Patients		Methods			Uptake (mean \pm sd%)			
	No.	Age range	HI	Directions	RDC	AC	Total	Right	Left
Gordon, et al. ^{(8)*}	21	u.k.	6	posterior	lateral view	-0.099	44.1 \pm 3.7 (36.7-51.5)	21.4 \pm 2.0 (17.4-25.4)	22.7 \pm 2.3 (18.7-27.3)
Morris, et al. ^{(9)*}	108	3 m-15 yr	4	anterior & posterior	geometric	-0.13	47.3 \pm 9.2 (27.1-77.1)	23.4 \pm 4.6 (13.7-37.7)	24.0 \pm 5.1 (13.6-41.4)
Groshar, et al. ^{(11)*}	30	1 yr-11 yr	6	SPECT	SPECT	u.k.	49.6 \pm 7.3 (46.1-53.1)	24.3 \pm 3.7 (23.6-26.0)	25.3 \pm 4.1
Authors	68	2 m-13 yr	2	posterior	height & weight	-0.153	40.7 \pm 5.0 (29.0-51.7)	20.2 \pm 3.0 (13.5-28.0)	20.4 \pm 2.7 (14.1-26.1)

*Reference

Abbreviations; m: month, yr: years, HI: hours after injection, RDC: renal depth correction, AC: attenuation coefficient, u.k.: unknown

correction which we used, the conjugative-view method (by means of the anterior and posterior imaging) and the SPECT method. He said that our method overestimated renal uptake more than other methods. Nevertheless, our present results were smaller than those calculated with other methods. This may be due to other factors such as acquisition timing. He showed that calculated data correlated significantly with those estimated by other methods. % RU of normal kidneys in our study did not show a wide range compared to those previously reported. Morris et al.⁹ reported normal renal values calculated by the conjugative-view method showing a wider range than ours. One of the reasons for this wide range may be the different attenuation caused by different organs, intestines in front of and muscles behind the kidneys, although the same attenuation coefficient was used for the correction.

As to acquisition time as another factor influencing the quantification of % RU, most previous reports pro-

posed 6 hours after injection as reasonable timing^{8,11,23} because renal uptake of ^{99m}Tc-DMSA increases for 6-8 hours and then reaches a plateau.^{1,10,11} In our hospital, we have performed both imaging and estimating % RU 2 hours after injection. The main reason for this timing is to shorten the patient waiting time to avoid additional sedation of patients. Our smaller estimated % RU may be due to this early timing compared to other methods. We previously investigated the time course of uptake of ^{99m}Tc-DMSA in 12 patients (including adult patients).⁵ Net counts in the region of interest over the kidneys increased as a function of time and reached a plateau 2 hours after injection, whereas % RU, corrected with physical decay and renal depth, increased for up to 4 hours. Flower et al.¹⁹ compared renal uptake of ^{99m}Tc-DMSA 2 hours and 4 hours after injection with that at 6 hours. Measured renal uptake (mean \pm sd) at 2 hours was 0.79 \pm 0.06 of that at 6 hours. Standard deviation was

reasonably small, although it was smaller at 4 hours (mean \pm sd: 0.94 ± 0.04). Calculation of the renal uptake of ^{99m}Tc -DMSA at 2 hours after injection is reasonable for routine clinical use, shortening the patient's waiting time and avoiding additional sedation, which have great benefits in actual practice in children.

Age-independency of % RU was shown in the present study. Morris et al.⁹ and Evans et al.¹⁰ reported similar results, whereas Groshar found slight reversed correlation between age and % RU.¹¹ This difference may be caused by the difference in the methods for calculation. Age-independency makes it possible to use % renal uptake at follow up of renal function in children, especially in children with VUR who need long term follow up.

The coefficient of variation in multiple measurement of % RU in 9 patients ranged from 1.2 to 18.4%. In a patient whose coefficient of variation was 18.4%, the first renal uptake was measured at the age of 2 months. First % renal uptake was measured as 27.3% whereas the renal uptake measured at between 1 and 4 years-old ranged from 42% to 45.3%. It is reported that the maturation of the kidney tubules is almost completed at 6 months of age.²⁴ Therefore, there is a possibility of incompleteness of maturation of the kidney tubules at the age of 2 months. The difference of region of interest size drawn by different operators might have caused great value of coefficient of variation, 12.0%, in another patient. In the remaining 7 patients, coefficients of variation were under 7.5%. They were reasonably small for evaluation of renal uptake at follow up.

In conclusion, our conventional method for quantifying % renal uptake is simple, practical and feasible for routine clinical use, especially in children during follow up.

APPENDIX

Total and individual percent renal uptake (total % RU, right % RU and left % RU) is calculated by means of the following formula:

$$\text{Total \% RU} = \text{right \% RU} + \text{left \% RU}$$

$$\text{Right \% RU} = R_{\text{net}}/e^{-0.153 D_r}/(D_0 \times T_{\text{past}})$$

$$\text{Left \% RU} = L_{\text{net}}/e^{-0.153 D_l}/(D_0 \times T_{\text{past}})$$

$$R_{\text{net}} = R_{\text{roi}} - R_{\text{bg}}, L_{\text{net}} = L_{\text{roi}} - L_{\text{bg}}$$

$R_{\text{roi}}, L_{\text{roi}}$: count in the region of interest right (R_{roi}) or left (L_{roi}) kidney

$R_{\text{bg}}, L_{\text{bg}}$: count in background of the right (R_{bg}) or left (L_{bg}) kidney

0.153: the linear attenuation coefficient of ^{99m}Tc
 D_r, D_l : distance from skin to right (D_r) or left (D_l) kidney

$$D_0 = (C_{\text{pre}} - C_{\text{post}})$$

C_{pre} : preinjection syringe count

C_{post} : postinjection syringe count

$$T_{\text{past}} = (1/2)^{-(T_{\text{exam}}/6.04)}$$

T_{past} : physical decay of ^{99m}Tc from the time of injection to data acquisition

tion to data acquisition

T_{exam} : time between injection and data acquisition

6.04: physical half life of ^{99m}Tc

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