

Quantitative SPECT Uptake of ^{99m}Tc -Dimercaptosuccinic Acid by the Kidneys in Children

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The normal range of values for quantitative SPECT of ^{99m}Tc -dimercaptosuccinic acid (DMSA) uptake by the kidneys in children was studied. **Methods:** Renal functioning volume, percentage of injected dose per cubic centimeter of renal tissue (%ID/cm³) and individual kidney uptake of 270 kidneys performed on 135 children, aged 2 wk–15 y, provided the basic data for this study. The accrual was part of the work-up of children with urinary tract infection where no structural or functional abnormalities of the renal tract could be established. Children were grouped according to age intervals, and a distribution chart was obtained with 2 SD above and below the mean of the values obtained for volume (%ID/cm³) and kidney uptake in each age group. **Results:** A significant correlation was found between age and functional volume ($r = 0.90$; 95% confidence interval [CI], 0.88–0.92; $P = 0.000$), and a significant inverse correlation was found between age and %ID/cm³ ($r = -0.86$; 95% CI, -0.88 to -0.82 ; $P = 0.000$). No statistically significant correlation was found between age and kidney uptake ($r = -0.20$; 95% CI, -0.32 to -0.09 ; $P = 0.001$). **Conclusion:** It seems that the normal maturational changes in renal function observed in infants and newborns do not affect the kidney uptake of ^{99m}Tc -DMSA. Thus, quantitation of ^{99m}Tc -DMSA uptake by the kidneys can be used to assess changes in the individual renal function over time in this age group.

Key Words: dimercaptosuccinic acid; SPECT; renal function; pediatrics

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Tchnetium- 99m -dimercaptosuccinic acid (DMSA) has been used as a renal cortical imaging agent to detect parenchymal abnormalities in children (1–5). Scintigraphy provides an image of the functional renal parenchyma, and the renal uptake of ^{99m}Tc -DMSA has been shown to correlate well with the effective renal plasma flow, glomerular filtration rate and creatinine clearance (6–8). Thus, the renal uptake of ^{99m}Tc -DMSA provides a practical index for evaluation of individual renal function. Little information on the normal range of the DMSA uptake by the kidneys in

children is available, especially in those younger than 3 mo (9–14). In the present report, quantitative SPECT of DMSA uptake by the kidneys (QDMSA) was obtained for children aged 2 wk–15 y.

MATERIALS AND METHODS

Patient Population

^{99m}Tc -DMSA quantitative SPECT study of 270 kidneys performed on 135 children, 87 girls and 48 boys, aged 2 wk–15 y (mean, 53 ± 51 mo), provided the basic data for this study. The accrual was part of the work-up of children with urinary tract infection for whom no structural or functional abnormalities of the renal tract could be established.

Quantitative SPECT

The technique has been discussed in detail previously (15) and will be described here briefly. Quantitative SPECT of DMSA uptake by the kidneys was measured using the same methodology as in previous studies (9,15,16). The patient was injected with 0.750–2 mCi ^{99m}Tc -DMSA, and SPECT was performed after 4–6 h. The exact dose injected was obtained by measuring the syringe in a dose calibrator before and after injection. The amount of radioactivity was corrected for decay from the time of injection to the time the study was actually performed. The studies were performed using a rotating gamma camera and an all-purpose, low-energy collimator (Apex 415-ECT; Elscint, Haifa, Israel). Data acquisition lasted 20 min and required 120 projections (3° apart), and the entire study accumulated $3\text{--}5 \times 10^5$ counts. Raw data were reconstructed by filtered back-projection with a Hann filter with a cutoff point of 0.5 cycle/cm. After reconstruction, each image was sectioned at 1-pixel (0.68 cm) intervals in the transaxial, coronal and sagittal planes using a 64×64 -byte matrix. Kidney volumes and radioactive concentration measurements were calculated on the transaxial reconstruction data using the threshold method. After performing a series of phantom measurements using volumes of 30–3800 cm³ and concentrations between 0.01 and 3.6 $\mu\text{Ci}/\text{cm}^3$, a threshold value of 43% was found to be optimal for ^{99m}Tc (15,17).

The operator chose the slice to define the kidney and drew a region of interest around the organ. For volume measurements (in cubic centimeters), the number of pixels containing activity greater than the threshold in all sections multiplied by the slice thickness was calculated. For concentration measurements, the threshold value was subtracted from all pixels in the regions of interest in all slices. All the nonzero pixels with higher counts than the threshold value were used to calculate the concentration. Counts per voxel

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were converted into concentration units (in $\mu\text{Ci}/\text{cm}^3$) using the regression line obtained previously by phantom measurements (17). The percentage of injected dose per cubic centimeter of renal tissue ($\%ID/\text{cm}^3$) was calculated using this value corrected for radioactivity decay. Kidney uptake was then obtained by multiplying kidney volume (in cubic centimeters) and $\%ID/\text{cm}^3$ (15). Excellent correlation has been found between actual concentration in kidney phantoms and SPECT-measured concentration (9), and a coefficient of variation for replicate studies of $<2\%$ was also found in phantom studies (18), indicating that the method can be reliably used to measure the concentration of $^{99\text{m}}\text{Tc}$ -DMSA in the kidneys.

Statistical Methods

Values are expressed as means \pm 1 SD. The paired *t* test was used to compare left vs. right kidneys. The functional volume, $\%ID/\text{cm}^3$, and kidney uptake were correlated to age using Spearman's coefficient of rank correlation. A distribution chart was obtained with 2 SD above and below the mean of the values obtained for volume, $\%ID/\text{cm}^3$, and kidney uptake in each age group.

RESULTS

Children were grouped according to age intervals as shown in Table 1. There was no statistically significant difference between right and left kidneys concerning the volume, $\%ID/\text{cm}^3$, and uptake in each age group. Table 1 lists the QDMSA results in each age group with a total of 270 (right and left kidneys) QDMSA determinations obtained from 135 children. A significant correlation was found between age and functional volume ($r = 0.90$; 95% confidence interval [CI], 0.88–0.92; $P = 0.000$), and a significant inverse correlation was found between age and $\%ID/\text{cm}^3$ ($r = -0.86$; 95% CI, -0.88 to -0.82 ; $P = 0.000$). No statistically significant correlation was found between age and kidney uptake ($r = -0.20$; 95% CI, -0.32 to -0.09 ; $P = 0.001$). Figures 1–3 represent the mean volume,

TABLE 1
QDMSA Results in Each Age Group*

Age (mo)	No. of kidneys (n)	Volume (cm^3)	$\%ID/\text{cm}^3$ (%)	Uptake (%)
0–2	22	40.5 \pm 8.7	0.63 \pm 0.15	25.1 \pm 4.4
2–4	20	43.5 \pm 7.8	0.58 \pm 0.16	24.9 \pm 5.5
4–6	24	48.6 \pm 14.0	0.63 \pm 0.16	29.4 \pm 5.0
6–12	22	55.2 \pm 12.9	0.47 \pm 0.11	26.4 \pm 3.2
12–24	24	64.7 \pm 13.1	0.43 \pm 0.09	27.3 \pm 3.4
24–48	30	75.4 \pm 10.7	0.34 \pm 0.09	25.2 \pm 4.5
48–72	50	91.2 \pm 14.8	0.29 \pm 0.08	25.9 \pm 4.9
72–96	26	111.0 \pm 16.1	0.22 \pm 0.05	24.0 \pm 3.8
96–120	14	107.0 \pm 24.8	0.24 \pm 0.03	25.5 \pm 3.2
120–144	18	142.7 \pm 39.9	0.17 \pm 0.04	23.8 \pm 3.1
144–180	20	161.0 \pm 32.3	0.15 \pm 0.05	23.1 \pm 4.1

*Values are expressed as means \pm 1 SD.

QDMSA = quantitative SPECT of $^{99\text{m}}\text{Tc}$ -dimercaptosuccinic acid; $\%ID/\text{cm}^3$ = percent of injected dose per cubic centimeter; uptake = kidney uptake.



FIGURE 1. Mean volume (line) \pm 2 SD (shadow area) versus each age group.

$\%ID/\text{cm}^3$, and kidney uptake, respectively, related to age with 2 SD above and below the mean.

DISCUSSION

Renal cortical scintigraphy using $^{99\text{m}}\text{Tc}$ -DMSA has been used for detecting renal cortical defects (1–5,19,20). Functional imaging of the proximal renal tubular mass is obtained that is dependent on the renal blood flow and proximal tubular cell membrane transport function (3,6). The quantitation of $^{99\text{m}}\text{Tc}$ -DMSA uptake in each kidney separately provides a practical index of absolute renal function (6–9,11,14–16,21–23). Planar and SPECT techniques have been reported for measurement of the percentage uptake of injected radioactivity of $^{99\text{m}}\text{Tc}$ -DMSA by the kidneys (6–16,21–27).

Absolute quantitation of a radiopharmaceutical by SPECT is feasible and has been shown to be a clinically reliable and useful technique (9,15,25–29). It can be considered in two levels: measurement of volumes and measurement of absolute radionuclide concentrations. Thus, QDMSA provides information concerning the percent of injected dose per cubic centimeter of renal tissue and functional kidney volumes. By multiplying these two parameters, individual kidney uptake is obtained. In adults, it has been shown that QDMSA is useful in separating normal from diseased kidneys (15), and a good correlation was found between

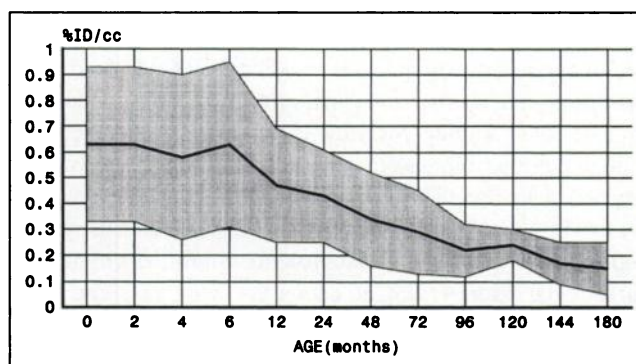


FIGURE 2. Mean $\%ID/\text{cm}^3$ (line) \pm 2 SD (shadow area) versus each age group.

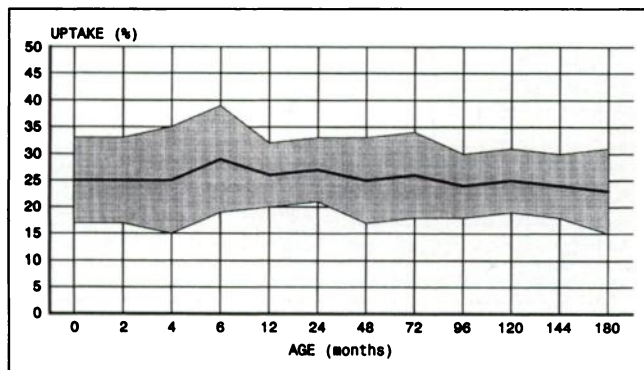


FIGURE 3. Mean kidney uptake (line) \pm 2 SD (shadow area) vs. each age group.

QDMSA in single kidneys and renal function measured by creatinine clearance ($r = 0.76$) (16) and serum creatinine ($r = 0.83-0.89$) (15,16), validating the measurements in each kidney separately. Also, QDMSA has been shown to be a reproducible method that can be used to monitor serial changes in individual renal function with a precision of 7.1% (30).

Determination of the ^{99m}Tc -DMSA uptake by the kidneys has been used to evaluate individual renal function in children (9-14,22-24,28,29). The value of absolute quantitation of DMSA uptake by the kidneys in children with vesicoureteral reflux and ureteropelvic junction obstruction has been reported (9,12,13,28,29,31). In children with vesicoureteral reflux, it was shown that QDMSA could be used as a noninvasive method for the assessment of impairment and contralateral compensation of the function of the individual kidney (9) and that QDMSA $<15.6\%$ represents functional damage with renal growth impairment (28). The method also showed increased functional volume in kidneys with ureteropelvic junction obstruction that may represent a compensation mechanism of renal function to counterbalance for the obstruction (29). However, little is known about the normal DMSA uptake by the kidneys in children younger than 3 mo (9,10,12-14,24).

In this study, a QDMSA distribution chart for children aged 2 wk-15 y was obtained from a pediatric population with previous urinary tract infection and no renal functional or structural abnormalities. Because performing radionuclide studies in normal children is not justified, it was decided to use this population as controls. The derived chart may provide a normal/abnormal criterion for the evaluation of individual kidney function in children. The functional kidney volume increased with age, and the $\%ID/\text{cm}^3$ decreased with age. These findings are in agreement with a previous report in a smaller sample of control kidneys (9) and with the fact that, in the growing child, the glomerular surface per kidney weight decreases with age, and each functional unit of the kidney has available to it the same blood supply as in adults (32). A wide range of normal values for kidney uptake was found similar to that noted by others (9,10,12,13). The normal kidney uptake of ^{99m}Tc -

DMSA found in this study in children was higher than that reported in adults (15,30). However, there was no trend in the variation of the kidney uptake with ages from 2 wk to 15 y. These findings are in agreement with those of others studying children older than 3 mo (10) and 1 y (12,13).

CONCLUSION

It seems that the normal maturational changes in renal function observed in infants and newborns do not affect the kidney uptake of ^{99m}Tc -DMSA. Thus, quantitation of ^{99m}Tc -DMSA uptake by the kidneys can be used to assess changes in the individual renal function over time in the pediatric population.

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