Renal Function and Technetium-99m-Dimercaptosuccinic Acid Uptake in Single Kidneys: The Value of In Vivo SPECT Quantitation

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The ability to evaluate kidney function in each kidney separately by quantitative SPECT was tested in 20 patients with a single kidney and varying degrees of renal disease. Technetium-99m-dimercaptosuccinic acid (^{99m}Tc-DMSA) uptake was compared with renal function measured by creatinine clearance and serum creatinine. There was a good correlation for both serum creatinine (r = 0.89, y = 24.6 *X^ −1.15, error = 5.6, p<0.001) and creatinine clearance (r = 0.76, y = 0.6 *X^ 0.84, error = 8.0, p < 0.001). The results indicate that SPECT quantitation of ^{99m}Tc-DMSA uptake can be used as an indicator of the function of each kidney individually.

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The evaluation of the function of each kidney, separately, is important in the initial assessment and follow-up of patients with renal disease (*1*). Bilateral ureteric catheterization for the measurement of individual kidney function is the most accurate method to evaluate renal function, but it carries the risk of trauma and infection associated with discomfort to the patient (*2*). Numerous radioisotope techniques have been proposed to measure renal function and this large number may reflect their limitations (*3–5*). Radiopharmaceutical determination of effective renal plasma flow or glomerular filtration rate has not gained universal acceptance. Blood sampling requirements and the length of the study may be sometimes impractical at busy nuclear medicine departments (*1,3*).

The renal uptake of technetium-labeled-dimercaptosuccinic acid (DMSA) has been shown to provide a practical index for evaluation of individual kidney cortical function (*6*). However, the need for correction for depth and background limits the usefulness and prevents widespread acceptance of this technique for quantitation of Tc-DMSA uptake by planar scintigraphy (*1,2*). Measurement of Tc-DMSA concentration by SPECT has been achieved using a threshold method (*7*). The reliability of the SPECT technique has been shown by extensive phantom studies which demonstrated a good correlation between the actual activity in the kidney phantoms and that measured by SPECT. In the present study, we have attempted to determine if the index provided by SPECT quantitation of DMSA uptake by the kidneys is an accurate indicator of the function of each kidney separately.

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MATERIALS AND METHODS

Patient Population

Twenty Tc-DMSA SPECT studies of the kidneys were performed on 20 patients 6 hr after the i.v. injection of 2–4 mCi of the radiopharmaceutical. There were twelve post-nephrectomy patients, two patients with unilateral renal agenesis, one patient with renal artery thrombosis, and five patients with longstanding nonfunctioning of one kidney as determined by ultrasound, i.v. urography, and renal (^{99m}Tc-DTPA) scintigraphy. Patients had a known single kidney. There were eleven females and nine males with a mean age of 53 yr (range 25–74). Creatinine concentration in the serum and the creatinine secretion in a 24-hr period were determined. Collection of urine was obtained on the day of the SPECT study and the creatinine clearance was calculated (ml/min). The creatinine was analyzed by random access autoanalyzer ("Monarch" Instrumentation Laboratories, Lexington, KY).

SPECT Method

Concentration of Tc-DMSA in the individual kidneys was determined using the previously reported SPECT technique (*7, 8*). The studies were performed using a rotating gamma camera and an all-purpose low-energy collimator (Elscint Apex 415-ECT, Haifa, Israel) and data were stored on an optical disc. Data acquisition lasted 20 min and required 120 projections 3° apart, using a 64 × 64 byte mode matrix. The entire study accumulates 3–5 × 10^5 counts. After reconstruction of the raw data, each image was sectioned at 1-pixel (0.68 cm) intervals along the transaxial, sagittal, and coronal planes. A computer program described to calculate kidney volumes and radioactive concentration based on a threshold value of 43% was used.

In a series of phantom studies which evaluated different thresholds, it was found that a threshold of 43% gave the smallest error in a wide range of volumes and concentrations (*8*) and was suitable for clinical measurement of various organs (*7–10*). It should be realized that when other equipment or other reconstruction algorithms are used, the threshold value and SPECT values of phantom concentration used for conversion of counts/voxel to μCi/cc should first be evaluated. In addition, a series of phantom measurements as previously reported should be performed. Also, the performance of the system should be routinely checked using the NEMA guidelines. A series of phantoms of different volumes and concentrations should also be tested every 6 mo. The method does not require calibration before each study if routine camera quality control is performed.

A region of interest (ROI) was drawn around the kidney, and for volume measurements the number of pixels in all sections multiplied by the slice thickness (0.68 cm) is summed. For concentration measurements, the threshold value was subtracted from all pixels in the ROI in all slices. All the non-zero pixels which have higher counts than the threshold value were used to calculate concentration. Counts/voxel were converted to μCi/cc using the regression line obtained previously by phantom measurements (*8*). The program asked for the amount of injected activity. The percent of injected dose per cc (%ID/cc) was calculated using this value corrected for radioactive decay. Kidney uptake then was obtained by multiplying the kidney volume and %ID/cc. Quantitation did not require more than a SPECT study and a few seconds of analysis on a 32-bit microprocessor (Elscint SP-1 computer analysis).

Technetium-DMSA uptake measured by SPECT and renal function as measured by serum creatinine and creatinine clearance were correlated.

RESULTS

The patient population investigated had varying degrees of impaired renal function, which resulted in different creatinine clearance and serum creatinine values. The range for serum creatinine values was 0.7%–7.5 mg% with a mean of 2.02 mg%, and the range for creatinine clearance was 5.2 to 114.8 ml/min with a mean of 58 ml/min. Technetium-99m-DMSA uptake ranged from 1.7% to 39% with a mean of 19.4%. A good correlation (power nonlinear least squares) was found between the Tc-DMSA uptake measured by SPECT and creatinine clearance (r = 76, y = 0.60$*$ X$\hat{}$ 0.84, error = 8.04, $p < 0.001$) (Fig. 1) and with the serum creatinine (r = .89, y = 24.6$*$ X$\hat{}$ −1.15, error = 5.6, $p < 0.001$) (Fig. 2).

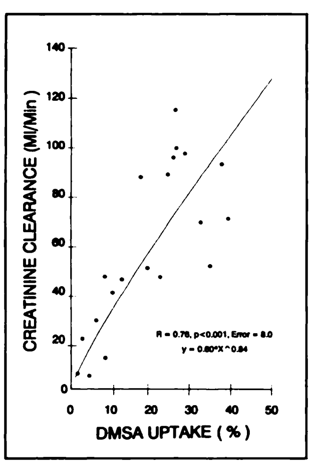

FIGURE 1. Comparison between creatinine clearance (ml/min) and Tc-DMSA uptake using SPECT.

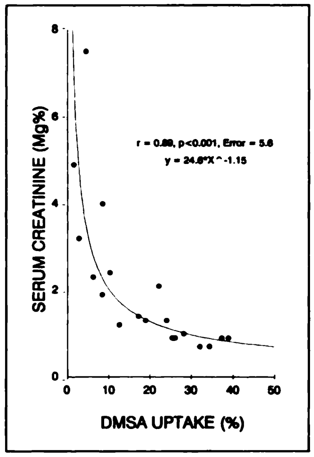

FIGURE 2. Comparison between serum creatinine (mg%) and Tc-DMSA uptake using SPECT.

DISCUSSION

There is an obvious need for a reliable noninvasive method for the assessment of the individual kidney function. Excretory urography, ultrasound, and computerized tomography provide anatomical information, but only gross information on renal function. A simple radionuclide technique for measurement of individual kidney function has not yet been generally adopted. The methods for measurement of glomerular filtration rate and effective renal plasma flow from plasma clearance of ^{99m}Tc-DPTA and ^{131}I-hippuran are quite accurate but are cumbersome and take a long time to perform. Clinical methods based on imaging alone are less accurate (*3*). SPECT technology is now available in most nuclear medicine departments. Quantitative SPECT is a reliable method for determining the concentration of radiopharmaceuticals in various organs (*8*). The study requires only 20 min; data analysis is practically automated and non-operator-dependent, with a very low intraobserver variability (*8,10*).

In a previous study (*7*), we have shown that the individual absolute kidney uptake of DMSA measured by SPECT is useful in separating normal from diseased kidneys. Also, it was demonstrated that a single normal kidney had an individual uptake higher than that in each of the kidneys of patients with two normal kidneys. The absolute uptake of a normal single kidney averaged 84% of the total uptake of both kidneys (right and left). This finding is similar to that of others who found that the creatinine clearance in a single kidney averaged 74.3% of normal in patients 23 yr after nephrectomy (*11*). In the present paper, the value of quantitative SPECT as an index of renal function was studied. To evaluate the method, we compared Tc-DMSA uptake in patients with single kidneys with the common laboratory criteria for kidney function—serum creatinine and creatinine clearance. A good correlation was found between the uptake of Tc-DMSA measured by quantitative SPECT with renal function measured by creatinine clearance (r = 0.76) and serum creatinine (r = 0.89).

In a previous study (*7*), we showed that quantitative SPECT allows absolute quantitation of individual renal uptake of Tc-DMSA. The present study, by showing a correlation between kidney function and Tc-DMSA uptake in a single kidney, even when the absolute uptake is higher in this kidney than in both kidneys of a normal person, indicates the validity of measurements in each kidney separately.

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