Evaluation of Renal Functional Image Using Tc-99m DTPA

MASATOSHI ISHIBASHI, SEIICHIRO MORITA, NORIYOSHI UMEZAKI, KIYOSHI YANO* AND HISASHI OHTAKE

Department of Radiology, Kurume University School of Medicine and *St. Mary's Junior College of Nursing, Kurume, 830 Japan.

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Summary: Functional Image (FI), which represents dynamic local renal function in one image, has been made possible only by digital image processing. The first FI obtained by rapid bolus injection of the radiolabeled medium is considered to be useful for evaluation of initial local renal blood flow. FI has the advantage that it can be performed simultaneously with conventional routine examinations of the renal function.

Key words: Functional Image—Tc-99m DTPA—kidney—renal circulation—Captopril

Introduction

Functional Image (FI), which visually represents the movement of the tracer in the kidney, is advantageous in that dynamic renal function can be evaluated pixel by pixel in one image.

We prepared FI of the blood flow, parenchymal function, and excretion of the kidney determined from the renogram curve. FI of the renal first blood flow, the technique of which we developed, was also evaluated.

Materials and Methods

The subjects were 14 males and 5 females including 5 normal individuals evaluated by clinical laboratory examination, intravenous pyelography, ultrasonography, X-CT, renal biopsy, and immunological studies. They ranged in age from 7 to 58 years with a mean of 38.7 years.

1) Radiolabeled agent and its dose:

Tc-99m (Sn) DTPA was administered to adults at a dose of 15 mCi (555 MBq). In children, the dose was adjusted according to their body weight.

2) Pre-treatment:

The subjects urinated 30 minutes before the examination and drank water (300 ml).

3) Apparatus:

A gamma camera (GCA 401-5, Toshiba), a low-energy general-use collimator, and a data processor (GMS-80 A, Toshiba) were used.

4) Data collection:

(1) The subjects were placed in the supine position, and the gamma camera was positioned over their back.

(2) The right upper arm was lifted to 90° in a slightly valgus position, and Tc-99m DTPA (15 mCi) was rapidly injected as a bolus at a rate of about 2 ml/sec.

(3) Scintigrams were obtained a total of 147 frames over a 30-minute period from immediately after the injection with a 64×64 matrix at a rate of 1 frame/sec.
for the first 1 minute and 1 frame/20 seconds for the remaining 29 minutes.

4) The data were stored on a magnetic tape. The Region of Interest (ROI) was set at the entire kidney, and the cut off level at 0%.

5) Time activity curve was drawn at each pixel (Fig. 1), and images of the First T max (FT max), First C max (FC max), and FC max/FT max for the first 1 minute after the injection (Fig. 2), and T max, C max, T 1/2, and C max/T max for the 30 minutes were produced on the CRT.

Results

The C max image is constructed from the maximum count during the 30-minutes period, the T max image from T max value, and the C max/T max image represents the renal function at each pixel.

The FC max is the maximum count at the first peak after the injection, and the FC max image shows the distribution of the count of blood flow during the first pass. The FT max image represents the differences in the time phase during the first pass, and the FC max/FT max image shows the velocity distribution of the renal blood flow.

1) Normal subjects

Fig. 3 shows FI of a 36-year old male with normal renal function and no urinary abnormalities.

2) Hydronephrosis

Fig. 4 shows renogram curves and FI before and after the operation in a 7-year-old girl with left hydronephrosis. The pre-operative renogram curve of the left kidney is of the obstructive type, but that of the right kidney of the normal type. The pre-operative T max image suggested a delay in T max in the pelvis, and the C max image showed high counts in areas

<table>
<thead>
<tr>
<th>Disease</th>
<th>Cases</th>
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<tbody>
<tr>
<td>Normal</td>
<td>5</td>
</tr>
<tr>
<td>Essential hypertension</td>
<td>3</td>
</tr>
<tr>
<td>Hydronephrosis</td>
<td>2</td>
</tr>
<tr>
<td>Chronic glomerulonephritis</td>
<td>6</td>
</tr>
<tr>
<td>Others</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
</tr>
</tbody>
</table>
Fig. 4. Renogram curves and functional images before and after the operation in the hydronephrosis case.

Fig. 3. Functional image of normal case.

Fig. 5. Functional image of chronic glomerulonephritis case.

Fig. 6. First functional images before and after administration of Captopril in the essential hypertension case.
corresponding to the hydronephrotic lesion. The C max/T max images were uniform in both kidneys. The T 1/2 image showed a defect at the hydronephrotic area due to the lack of signals, indicating a marked delay of excretion. The post-operative renogram curve was of the obstructive-like type in the left kidney and of the normal type in the right. In FI, the area of delayed T max was reduced. The C max images were similar between the two kidneys, because there were no major changes in the renal function before and after the operation. The C max/T max image showed no marked differences between before and after operation. In the T 1/2 image, the pelvis, which was represented as a defect before the operation, was delineated after the operation, indicating resolution of hydronephrosis.

3) Chronic glomerulonephritis

Fig. 5 shows the renogram curves and FI of a 56-year-old male with chronic glomerulonephritis diagnosed by renal biopsy. The renogram curves of both kidney were of the normal type. The C max image of the left kidney showed no marked difference in the distribution from the cortex to the pelvis, but that of the right kidney showed high counts in the upper apical region. The T max image indicated a delay in T max of the renal parenchyma, and the C max/T max image suggested an area of good function in part of the cortex. T 1/2 image showed an even distribution.

4) Essential hypertension

Fig. 6 shows the first FI. The FT max image indicated in a delay of the occurrence of the maximum count in the upper apical region of the right kidney both before and after administration of Captopril, but the time distribution was nearly uniform in other areas. The FC max image disclosed an increase in the maximum count in the peripheries of the kidney after, as compared with before, the administration. These changes represent an increase in the cortical blood flow induced by Captopril administration.

Discussion

By the conventional method, FI was performed from the renogram curve based on the data collected for 30 minutes (Nishimura, 1977). We prepared FI of the first pass of the radioisotope injected as a bolus at about 2 ml/sec, because renal vessels are functional rather than anatomic vessels and renal circulation is closely related to renal function.

If hypertension persists, renal vessels and glomeruli are damaged, resulting in a reduction in renal function and impairment of water and Na excretion, which intensifies hypertension due to the increase in extracellular fluid. Renal circulation, therefore, is considered to play an important role in homeostasis of renal function (Honda, 1986). For these reasons, the first FI is considered to be useful for evaluation of the renal circulation.

The C max and T max images of patients with hydronephrosis indicate retention of RI at the lesions and clearly show the extent of the lesions. The distribution of the T max image widens as the damage of renal parenchyma due to hydronephrosis progresses (Nishimura et al. 1979). The C max/T max image is useful in that it graphically represents secondary renal damage due to the disease. The lack of changes in the C max/T max image in our patient between before and after the operation indicates that the operation itself had little effect on the kidney.

As for FI of patients with chronic glomerulonephritis, the C max image represents the RI uptake at each pixel, and the T max image closely reflects the time of interval RI transport. The C max/T max image reflects diffuse functional impair-
ment of the renal parenchyma.

In the first FI of patients with essential hypertension, the FC max image clearly shows an increase in the renal first blood flow after the Captopril administration, as the drug acts on two resistance vessels, namely the afferent and efferent arterioles from the medullary to cortical kidney. In the C max/T max image, the high activity area is widened, graphically indicating a reduction in renal vascular resistance.

FI represents the local blood flow, function, and excretion of the kidney in one digital image, and is considered to be useful for evaluation of the pathophysiology of kidney diseases.

References