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Studies of an aspect of renal function with the aid of dynamic CT and renogram.

Nobuo Satoh[*]   Shin Kimoto[†]

Yoshio Hiraki[‡]

[*]Okayama University,
[†]Okayama University,
[‡]Okayama University,

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Abstract

Dynamic CT scans were conducted on 94 persons who had been randomly selected among the patients and the volunteers. The test results were used to obtain the time-density curve. A part of the subjects (20 cases) underwent the renogram examination for the comparative studies. The cortico-aortic (CA) ratio derived from the time-density curve demonstrated good correlation between the dynamic CT and the renal function (r = 0.68). When the dynamic CT studies and the renogram were compared, the vascular phase of the renogram showed strong correlation with CA ratio. Consequently the dynamic CT study the CA ratio was believed to demonstrate the renal function.

KEYWORDS: dynamic CT, kidney, renogram

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Nobuo Satoh*, Shin Kimoto and Yoshio Hiraki

Department of Radiology, Okayama University Medical School, Okayama 700, Japan

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Computed tomography (CT) is superior to other modalities in density resolution, and is also useful in the detection of the lesions along with the evaluation of the range of their involvement in the diagnosis of the renal disorders (1, 2). In addition, the usefulness of CT has also been reported with respect to the evaluation of the renal function through the use of dynamic CT (DCT) (3–7). In this study, the time-density curves were obtained with renal DCT and various parameters were calculated based on those time-density curves to evaluate the renal function. Therefore, we studied the correlation between these results and the 24 h creatinine clearance (C_{cr}) results and also compared these with the renogram findings.

Materials and Methods

Dynamic CT was performed on 94 cases having various degrees of the renal function. The age of the subjects ranged from 76 years to 16 years and the average age was 54 years. The subjects consisted of 71 females and 23 males. The patients with urological diseases were as follows: 10 patients with bladder tumor, 9 patients each with prostatic hypertrophy, and renal cell carcinoma, 2 patients each with glomerulonephritis, and renal cyst, and 1 patient each with polycystic kidney, renovascular hypertension, pyeloureteral junctional stenosis, and chronic renal failure, respectively. The others had no urological disorders.

The TCT-900S (Toshiba Co., Tokyo, Japan) was used. Total 40 ml of Iopamidole (300 mgI/ml) was injected intravenously into the left forearms of the subjects at the rate of 5 ml per second followed by scanning. One second scans were performed making 10 slices at 2 sec intervals and 7 slices at 9 sec intervals (Fig. 1). The ROI were selected as widely as possible in the aorta, the renal cortex and medulla followed by measurement of CT

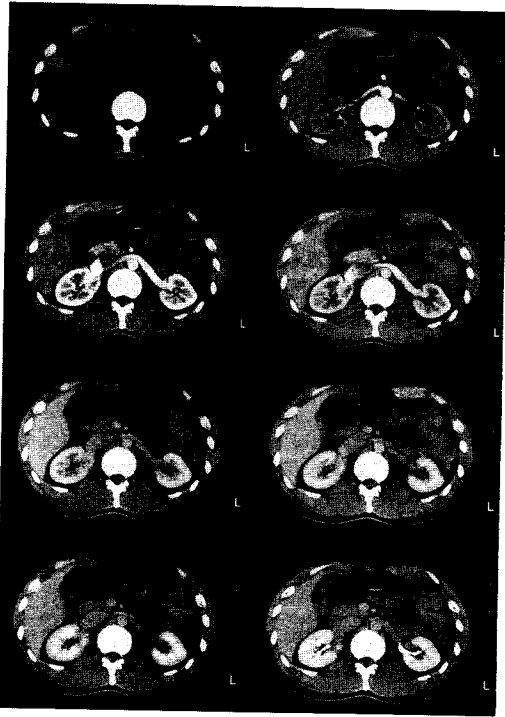* To whom correspondence should be addressed.

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Fig. 1 Dynamic CT images of the kidney. Scanning was started following injection of the contrastmedia. One second scans were performed making 10 slices at 2 sec intervals and 7 slices at 9 sec intervals. After the enhancement of the renal cortex, the medulla was enhanced followed by calyces opacification.

values. Together with this procedure, the time-density curves were prepared and additional studies were also performed on the parameters described below.

The parameters consisted of the cortex-medulla intersection time (CMT) (7, 8), the medullo-cortico (MC) ratio, the medullo-aortic (MA) ratio, and the cortico-aortic (CA) ratio. The CMT is the time at which the cortex curve intersects the medulla curves. Before determination of each ratio, the area under the aorta, the cortex, and the medulla curves that changed due to enhancement until an elapsed time of 100 sec, were calculated. The MC ratio was determined by dividing the area under the medulla curve by the area under the cortex curve. The CA ratio and the MA ratio were determined by dividing the area under the cortex and the medulla curves by that of the aorta, respectively.

For the renograms, following injection of 370 MBq of 99m-T_C-DTPA, data were collected at 2 and 8 sec intervals with the Toshiba GCA401 and processed using the Shimadzu Scintipack 2400.

The 24 h creatinine clearance (C_{cr}) was calculated using the 24 h urine volume and creatinine concentration of the urine and the serum.

The glomerular filtration rate (GFR) was determined by the following method. About 30 min after hydration with 500 ml water, 80 ml of 10 % sodium thiosulfate (Na_2 S_2O_3) was administered into an antecubital vein. About 25 min after injection, the patient was asked to micturate. Five ml of blood samples were obtained from the arm contralateral to the injection site, 10 min and 20 min after
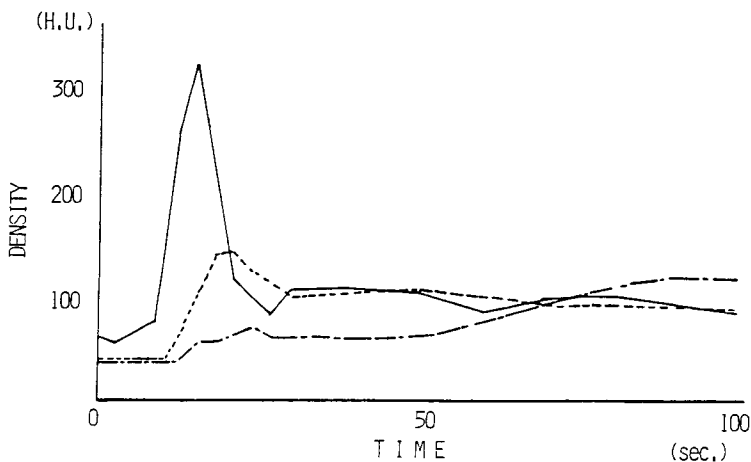

Fig. 2 Time-density curve of the normal volunteer. (——), Aorta; (----), Cortex; (—·—), Medulla.

voiding. Thirty min later the patient was asked to void urine again and the total voided urine volume was recorded. The GFR was calculated using the urine volume and sodium thiosulfate concentration of the urine and the plasma.

Results

Normal kidney. The aorta curve reached rapidly to the peak level within 15 sec after the injection of contrast media. It then gradually decreased and showed fluctuations due to recirculation. The cortex curve had a peak that was somewhat lower and later than that of the aorta curve. It then decreased. The medulla curve reached the peak even later than the peak of the cortex curve and then intersected the cortex curve at 50–60 sec (Fig. 2).

Hypofunctional kidney. In the time-density curve of the patient with polycystic kidney ($C_{cr} = 54.6 \, ml/min$), the peak of the cortex curve was lower, and the decline of the curve was smoother in comparison to that of the normal cases. With respect to the renal medulla, a delay and a

decrease of enhancement was observed. Delay was also observed in the intersection times of the curves of the medulla and the cortex (Fig. 3).

Parameters. The correlation between each parameter and C_{cr} were studied in 65 cases. In the correlation with the CMT, a satisfactory result was not obtained with the correlation coefficient being $r = -0.40$. In the correlation with the 1/CMT, the correlation coefficient was 0.50. With respect to the MC ratio and the MA ratio, the correlation coefficients were $r = 0.35$ and $r = 0.53$, respectively. The correlation coefficient between the CA ratio and C_{cr} was 0.68 (Fig. 4). The correlation of CA ratio was the most with C_{cr} among the parameters studied.

The correlation between each of the parameters and GFR were studied in 20 cases. The correlation coefficients between GFR and the CA ratio (Fig. 5), the MA ratio, the MC ratio and the CMT were 0.73, 0.64, 0.29 and -0.43, respectively. This study also showed that the CA ratio has a good correlation with GFR.

Renograms. The renograms were obtained from 20 cases (40 kidneys). Significant differences were observed in the parameters
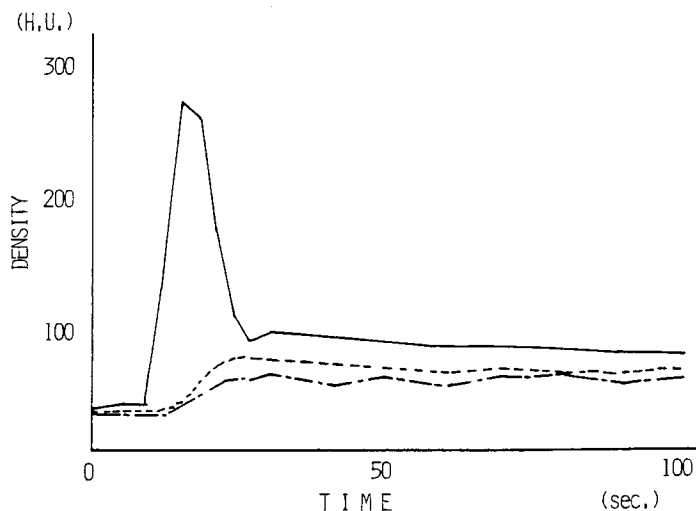

Fig. 3   Time-density curve of the patient with polycystic kidney ($C_{cr} = 54.6 \, ml/min$). (———), Aorta; (----), Cortex; (—·—), Medulla.
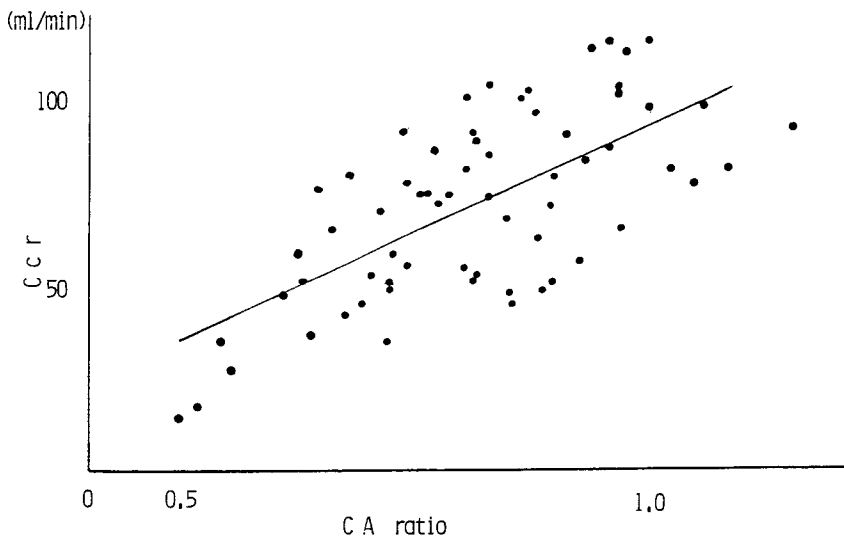
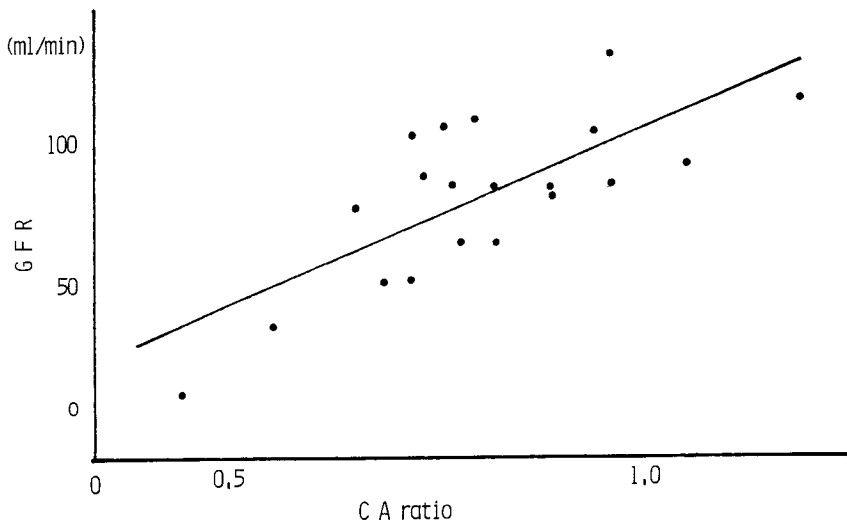**Fig. 4**   Correlation between C_{cr} and the CA ratio.   r = 0.68, n = 65

Fig. 5   Correlation between GFR and the CA ratio.   r = 0.73, n = 20

among each renogram patterns (Fig. 6).   In addition, the correlation coefficients between the time of the vascular phase and the MA and the CA ratios were -0.69 and -0.67, respectively.
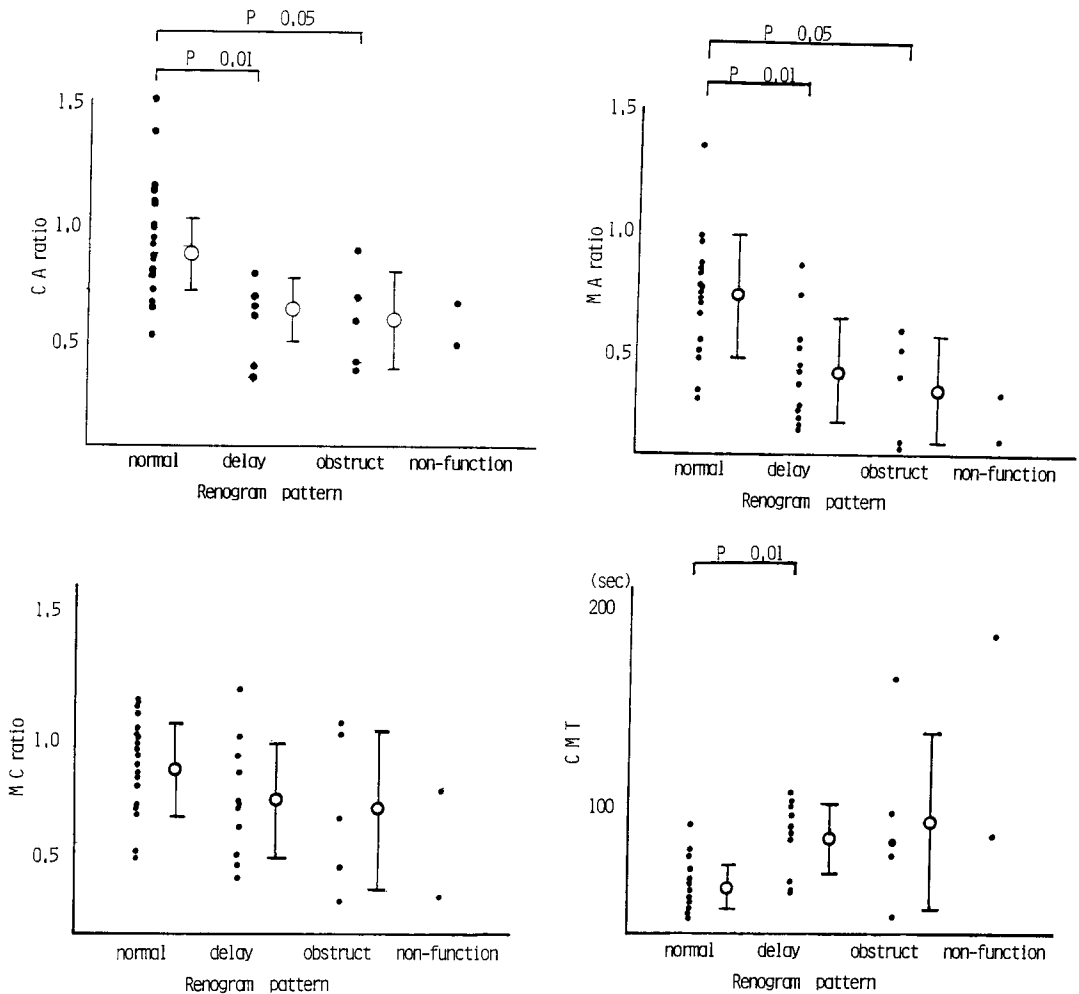
Fig. 6 Parameters between each of the renogram patterns. Significant differences were observed in the parameters among each renogram patterns.

Discussion

As high-speed scans on the order of 1 sec are possible now by using the next-generation CT, we were able to conduct the study in greater details especially in the vascular phase. In addition, cine-mode, which was available in this system was so useful for visual evaluation.

Normal time-density curves of our study demonstrated similar patterns to some of the reported ones (3–7). The peak of the aorta curve

appeared first, then the cortex curve reached a peak followed by that of the medulla curve. The vascular space per volume was the same in the medulla and the cortex, but the blood flow was less in the former than in the latter (9). The peak of the medulla curve is considered to correspond to the flow of contrast media into the tubules.

As previous studies have reported (3, 5–7), the majority of abnormalities in the hypofunctional kidneys observed with the DCT were reductions in the enhancement of the renal cortex and

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medulla and delays in the decline of density. Not only a decrease in the flow of contrast media in the medulla due to glomerular filtration, but also a decrease in the blood flow due to vascular disorders and also a reduction in the number of glomeruli themselves are considered to be the causes of these abnormalities.

Various efforts regarding the estimation of renal function with the DCT have been reported (10, 11). The peak value of the time-density curve, the slope of the rise, and the time until the peak were affected by the frequency of the scans. It was reported that the CMT was a reliable indicator of renal function because the CMT was affected very little (7). However, neither the CMT nor the 1/CMT was well correlated with C_{cr} in this study. The newly developed MC ratio, the MA ratio and the CA ratio, that were calculated as the parameters in this study demonstrated better correlation with C_{cr} and GFR. The closest correlation was obtained with the CA ratio. Therefore, it may be considered that this parameter is very useful as an indicator of renal function. The reasons are thought to be as follows. The CA ratio is thought to be able to eliminate the effects of cardiac function since this parameter include the elements of the aorta curve. And also this parameter is determined focusing on the renal cortex. Therefore, the information of the GFR could be estimated regardless of the urine concentration.

It was suggested that there was the possibility of estimating renogram patterns from the analysis of the DCT, since specific significant differences were observed to a certain extent in the parameters among each renogram patterns. Although renal uptake of 99 m-T_C-DTPA was reported to correlate with C_{cr} (12–15), it was also believed that the DCT was superior with respect to the quantitative evaluation of the renal function, because of its simplicity and possibility to estimate localized renal function. And it was reported that the results of the DCT did not correlate well with the results of either diuresis renography or measurement of parenchymal transit time (11).

However, those were thought to be mainly caused by its CT scanner and parameters.

In the evaluation of renal function, we believed that the CA ratio correlated with GFR values together with its time-density curve is a useful indicator of both split and localized renal functions. Therefore, the DCT will be able to be used as a substitute for the renogram in the future.

References

1. Segel SS, Stanley RJ, Levitt RG and Geisse G: Computed tomography of the kidney. Radiology (1977) **124**, 359–370.
2. Love L, Reynes CJ, Churchill R and Moncada R: Third generation CT scanning in renal disease. Radiol Clin North Am (1979) **17**, 77–90.
3. Ohyama Y, Imanishi Y, Ishikawa T, Fujii M and Uji T: Dynamic CT of the renal parenchyma. Gazouigakushi (1985) **4**, 821–831 (in Japanese).
4. Ishikawa T, Ohyama Y, Ashida H and Uji T: Clinical application of gated CT and dynamic CT. Eizou Jouhou (1980) **12**, 257–263 (in Japanese).
5. Ishikawa I, Onouchi Z, Saito T, Kitada H, Shinoda A, Ushitani K, Tabuchi M and Suzuki M: Renal cortex visualization and analysis of dynamic CT curves of the kidney. J Comput Assist Tomogr (1981) **5**, 596–701.
6. Ohyama Y: Dynamic CT of renal dysfunction. Jpn J Clin Radiol (1986) **31**, 589–594 (in Japanese).
7. Ishikawa I: Diagnostic imaging and function of the kidney. Rinsho Byohri (1987) **35**, 992–1001 (in Japanese).
8. Ishikawa I, Masazaki S, Saito T, Tateishi K, Kitada H, Yuri T, Shinoda A, Onouchi Z, Saito Y and Futyu Y: Dynamic computed tomography in acute renal failure: Analysis of time-density curve. J Comput Assist Tomogr (1985) **9**, 1097–1102.
9. Thurau K: Renal hemodynamics. Am J Med (1984) **36**, 698–719.
10. Yokoyama M, Watanabe S, Inatsuki S, Ochi K and Takeuchi M: Computerized tomography of the kidney: Tissue-plasma ratio of contrast enhancement with bolus injection and renal function. J Urol (1982) **127**, 721–723.
11. Neal DE, Simpson W, Bartholomew P and Keavey PM: Comparison of dynamic computed tomography, diuresis renography and DTPA parenchymal transit time in the assessment of dilatation of the upper urinary tract. Br J Urol (1985) **57**, 515–519.
12. Gary FG: Glomerular filtration rate: Estimation from fractional renal accumulation of 99 m-T_C-DTPA (Stannous). Am J Roentgenol (1982) **138**, 565–570.

13. Ito T, Takeda K, Toyota S, Maeda H, Kitano T, Nakagawa T and Yamaguchi N: Estimation of glomerular filtration rate from fractional renal uptake of $99m$-T_C-DTPA. Jpn J Nucl Med (1984) **21**, 1579−1586 (in Japanese).

14. Maeda M, Hasegawa R, Tanaka S and Yoshida H: Analysis of renograms with simultaneous injection of $99m$-T_C-DTPA and 131-I-OIH: Estimation of GFR, ERPF and retention function of individual kidney. Jpn J Nucl Med (1985) **22**, 1341−1352 (in Japanese).

15. Aburano T, Takayama T, Nakajima K, Seto M, Tonami N, Hisada K, Yamada M, Iida Y, Kawamura M, Matsudaira M and Miyazaki Y: Measurement of split glomerular filtration rate by fractional renal uptake of T_C-$99m$ DTPA. Jpn J Nucl Med (1985) **22**, 1781−1787.