Evaluation of the Therapeutic Effect of Percutaneous Nephroureterolithotomy by Tc-99m Diethylenetriaminepentaacetic Acid (DTPA) Renal Scintigraphy

—Alteration of the Renal Fraction of Blood Flow, Split-GFR, and Renal Mean Transit Time—

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Summary: To evaluate the therapeutic effects of percutaneous nephroureterolithotomy, the renal function of eleven patients with renal calculi was studied, pre- and post-intervention. Renal function was determined, by renal scintigraphy with the renal agent, Tc-99m diethylenetriaminepentaacetic acid (DTPA). In each renal scintigram the renogram curve was analyzed and the following were determined by deconvolution analysis; the renal fraction of blood flow (RFBF), DTPA-glomerular filtration ratio (GFR), and the renal mean transit time (MTT). The successful results in percutaneous nephroureterolithotomy (PNL) was proven using the radionuclide technique in most cases. From these results it can be concluded that renal scintigraphy is an effective procedure to evaluate the effect of PNL for treating renal calculi and secondary hydronephrosis.

Key words: Percutaneous nephroureterolithotomy (PNL)—Tc-99m diethylenetriaminepentaacetic acid—Renal fraction of blood flow—Glomerular filtration ratio—Deconvolution analysis

Introduction

Follow-up data on the evaluation of the therapeutic effects of percutaneous nephroureterolithotomy (PNL) may be not available. Moreover, although percutaneous endourological stone extraction is an accepted and safe technique for the treatment of urolithiasis, complications

from the procedure do occur (Clayman et al. 1984; Mayo et al. 1985; Vallancien et al. 1985). Since the collecting system is approached via a transparenchymal route, vascular and parenchymal damage are possibilities that could result in a loss of renal function reducing the therapeutic efficacy of percutaneous surgery. Recently, new methods using ultrasonic lith-

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otripsy have been developed (Marberger et al. 1982). The possibility that these methods represent an improvement in the endurological stone extraction will depend on their therapeutic efficiency, as demonstrated by an improvement in renal function after the intervention. To approach these issues, the therapeutic effect of PNL and its influence on renal function were evaluated using renal scintigraphy.

Subjects and Methods

Renal scintigraphy was performed on eleven patients with renal calculi, pre- and post-PNL. The post-PNL studies were performed within one month, except for 2 cases. The subjects urinated, 30 minutes before the examination, and were given 300 ml of water to drink. Tc-99m diethylenetriaminepentaacetic acid (DTPA) was injected intravenously to adults at a dose of approximately 15 mCi (555 MBq). Radionuclide data were acquired using a gamma camera (GCA 401-5, Toshiba Corp., Inc., Japan), with a low-energy general-use collimator, interfaced to a scintipac 2400 data processor (Shimadzu Corp., Inc., Japan). Follow-up studies were always obtained on the same instrument that was used for the pre-operative evaluation by the same investigator. The patients series was comprised of ten males and one female with a mean age of 44 years (range, 28-83).

Determination of region of interest with renal scintigraphy

A region of interest (ROI) was set for each kidney which encompassed the entire renal activity outline. The background was calculated from a curvilinear area set in juxtaposition to the lower pole of the kidney as determined by the renal ROI.

Renal fraction of blood flow

For the calculation of the renal fraction of blood flow (RFBF), ROI was set at the level of the renal artery, as previously reported (Ishibashi, 1987). RFBF was calculated as an integral value of activity from the time of appearance to the time of peak activity for one minute after injection.

The normal values from 7 subjects were determined as follows:

left kidney, $24.17 \pm 1.88\%$

right kidney, $21.05 \pm 1.27\%$

Mean transit time

ROI, as calculated by deconvolution analysis (Diffey et al. 1976), was set for the entire kidney, the background, and the aorta/renal artery. The normal value of mean transit time (MTT) was 2.70 ± 0.54 minutes (calculated from 20 normal subjects).

Glomerular arfiltration ratio

The DTPA-glomerular filtration ratio (DTPA-GFR) was calculated, as previously described (Ishibashi, 1987): $\text{DTPA-GFR} = 8.50 \times (\text{Tc-99m DTPA renal uptake ratio}) \pm 10.86$ ml/min (The calculation was derived from data acquired in 34 subjects).

Statistical analysis

The analysis was performed using the student's unpaired t-test. The data was expressed as mean $\pm$ 1SD.

Results

Fig. 1 demonstrates the radionuclide angiography, sequential images (5min-utes/acquisition), and renogram, pre- and post- PNL. In this case the renal function of the treated kidney improved.

On overall observation, the Ccr, split-GFR, MTT and RFBF are shown in the following figures. When the subject group

Fig. 1. RI angiographies, sequential static image sets, and renograms, pre- and post-percutaneous nephroureterolithotomy are shown from patients with successful therapeutic outcome.

was considered as a whole, no significant functional changes were found in the kidney after PNL. Some of patients experienced a slight decrease in renal function, but the magnitude of these changes were usually small in most instances.

Ccr in pre- and post- PNL (Fig. 2)

The 24 hour Ccr of pre- and post-PNL were not significantly different. All except 4 improved.

RFBF in pre- and post- PNL (Fig. 3)

The RFBF of pre- and post-PNL was

not significantly different, however, 6 of 9 patients had the RFBF that decreased slightly.

Split-GFR of pre- and post- PNL (Fig. 4)

The split-GFR of pre- and post-PNL were not significantly different. The split-GFR of 6 patients, however, decreased after PNL.

MTT of pre- and post- PNL (Fig. 5)

The MTT of pre- and post-PNL were significantly different ($p < 0.08$). In this group, 8 of 11 patients had an improvement of MTT.

Fig. 2. Twenty-four hour Ccr values, pre- and post- percutaneous nephroureterolithotomy, are demonstrated.

Fig. 3. The renal fraction of blood flow, pre- and post percutaneous nephroureterolithotomy, are demonstrated.

Fig. 4. The split-GFR, pre- and post-percutaneous nephroureterolithotomy, are shown.

Fig. 5. The MTT, pre- and post-percutaneous nephroureterolithotomy, are demonstrated.

TABLE 1
Data are shown.

No.	Sex Age	Side Postoperative days	Pre Post	Renogram (Type)	Ccr (ml/m)	Split-GFR (ml/m)	MTT (min)	RFBF (%)
1	M 29	R 20 days	Pre	M2	62.9	50.7	11.0	14.6
			Post	M2 like	113.6	43.8	8.8	18.0
2	F 35	L 4 days	Pre	M2 like	74.6	50.7	12.1	20.7
			Post	M2 like	89.2	45.6	9.1	24.2
3	M 82	L 46 days	Pre	M2	89.8	43.0	10.0	17.8
			Post	M1	108.0	20.7	3.5	20.1
4	M 34	L 10 days	Pre	M2 like	85.7	23.4	7.9	14.8
			Post	M1	48.8	16.8	3.8	13.8
5	M 54	R 11 days	Pre	N	83.8	61.3	3.5	18.0
			Post	M2 like	103.5	63.1	4.8	12.3
6	M 53	L 15 days	Pre	N	138.8	34.1	2.8	28.2
			Post	N	77.5	40.2	4.2	27.0
7	M 44	L 59 days	Pre	N	68.8	51.5	2.8	27.3
			Post	N	48.8	46.0	3.7	23.7
8	M 59	R 15 days	Pre	N	97.0	27.1	2.6	21.6
			Post	M1	57.8	21.3	2.3	19.7
9	M 28	L 9 days	Pre	M2	76.5	31.1	11.6	—
			Post	N	119.9	62.3	2.8	—
10	M 35	L 4 days	Pre	N	84.9	38.0	4.0	—
			Post	N	107.7	51.2	3.8	—
11	M 29	L 20 days	Pre	M2	62.9	28.4	12.7	23.2
			Post	M2 like	113.6	30.1	8.5	23.1

Discussion

Recently, PNL has become an increasingly popular procedure for stone removal. There are numerous reports regarding to stone removal using PNL on the morphology and function of the kidney (Alken et al. 1981; Ekelund et al. 1986; Schiff et al. 1986). To evaluate the renal function of the treated kidney using a radionuclide technique, the present study was carried out on 11 patients with renal calculi by PNL. The radiopharmaceutical used was Tc-99m DTPA. With respect to studies involving radionuclide techniques, Alken and co-worker (1981) reported the renal function using I-131 hippuran. Also, Ekelund and colleagues (1986) described the renal function embedded the influence of PNL using Tc-99m DTPA.

The renal function was assessed in 11 patients using Tc-99m DTPA, pre- and post- PNL (Ishibashi et al. 1989). The split-GFR from Gate's procedure (Gate,

1983; Gate et al. 1983) was calculated,

the MTT was based on the deconvolution analysis (Diffey et al. 1976), and the renal fraction of blood flow was based on a new intravenous injection technique and analysis (Ishibashi, 1987; Ishibashi et al. 1988). Further, the urine and serum of these patients were collected, simultaneously, and the 24 hour Ccr was calculated during PNL. Overall, the data addressed that the renal function was not significantly different, pre- and post- PNL. The MTT, however, reduced ($p < 0.08$).

The renal fraction of blood flow

Technetium-99m is the radiolabel of choice for the majority of nuclear medicine procedures because of its relatively short half-life, low radiation exposure, and its 140 keV gamma cameras have high detection efficiency and resolution. For this reason, this radiopharmaceutical was utilized. The renal perfusion could

be detected and the resultant renal fraction of blood flow could be determined. Accordingly, these parameters reflect the renal perfusion as previously described (Ishibashi, 1987; Ishibashi et al. 1988, 1989). The renal fraction of blood flow were not significantly different, pre- and post- PNL, but five of these patients were decreased by maximum of 5.7%. Of interest, we emphasize that the renal fraction of blood flow may be related to the vascular damage caused by PNL.

Webb and colleagues (1985) investigated the effects of PNL on renal function and anatomy in 15 dogs. In particular, angiograms were normal and there was minimal peripheral small vessel damage. There was no major intra-renal vessel damage at any stage. Nonetheless, our quantitative measurement of the renal fraction of blood flow in the present experiment indicates minimal peripheral small vessel damage. The renal function, pre- and post-PNL, should be calculated and evaluated on the basis of the renal fraction of blood flow.

Split-GFR

To evaluate the renal function, the GFR of treated kidneys was calculated using Gate's procedure (Gate, 1982; Gate et al. 1983). Overall, the change of split-GFR was not significantly different, pre- and post- PNL. Six of these patients, however, had a decrease of split-GFR. These data documented the slight change of split-GFR, except in 1 patient, in whom the split-GFR of decreased by 22.3 ml/min, and in another where the split-GFR decreased by approximately 7 ml/min.

Ekelund et al. (1986) described that the patients were hydrated and placed in front of the collimator for 18 minutes after the intravenous injection of Tc-99m DTPA. They calculated the normal function from kidney activities, 80 to 120 seconds after the injection of Tc-99m

DTPA. The decrease in renal function that they observed early after PNL was not surprising. The changes remaining after 2 weeks were rather small.

Shiff et al. (1986) reported that radiographic and functional analyses were carried out on 33 consecutive patients. The renal function was studied by radio-nuclide renography, both before intervention and at either 4 to 6 weeks or about 1 year, postoperatively. There were no statistically significant changes in renal function in the group of 33 patients as a whole, but one of the patients did exhibit a decreased function either in the whole kidney or in the cortical region of interest.

MTT

Overall, the change of split-GFR was not statistically significant, pre- and post- PNL. But the probability was 0.08. Three of these patients had the increase of MTT. The increase occurred within 1.4 min. Bamanji et al. (1987) evaluated pre- and postextracorporeal shock wave lithotripsy using the parenchymal transit time index (PTTI). On the other hand, the region of interest in the present study was the whole kidney. They described the distinction may be made by comparing the whole kidney mean transit time with the mean parenchymal transit time. The difference gives the pelvic transit time, provided the study has been continued long enough to accommodate the whole kidney transit time. The pelvic transit time is normal in ischemia but prolonged in obstructive nephropathy. Although MTT is global value, it may be sufficient to evaluate the degree of obstructive change or the delay of urine excretion.

Detection of complications from PNL

Percutaneous surgery for renal calculi has been accepted as a routine procedure after the early successful reports and the

economical advantages of a percutaneous over an open operation are obvious; but some complications have been reported, primarily bleeding and injury to the adjacent organs (Banner et al. 1985; Vallancien et al. 1985; Culkin et al. 1986). No complications were experimented in this study. However, the radionuclide technique could facilitate the detection of bleeding. Further, this technology may induce another complications.

In conclusion, the renal function in kidneys treated by PNL could be evaluated by a radionuclide technique. Of the resultant parameters, the renal fraction of blood flow was the most sensitive parameter, which may appreciate the minimal small vessel damage in the kidney treated by PNL (Ishibashi et al. 1989). PNL, also, doesn't affect the renal function as a whole.

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