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Scintigraphy and Doppler ultrasonography for the evaluation of obstructive urinary calculi

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Abstract

Forty-seven patients with unilateral obstructive calculi (12 males and 35 females) were submitted to ^{99m}Tc-diethylene triamine pentaacetic acid (DTPA) or ^{99m}Tc-dimercaptosuccinic acid (DMSA) scans for assessment of renal function. The scans revealed unilateral functional deficit in 68 and 66% of the patients, respectively. A calculus size of 1.1 to 2.0 cm was significantly associated with deficit detected by DTPA, but duration of obstruction and calculus localization were not. After relief of the obstruction, the mean percent renal function of the affected kidney was found to be significantly increased from 25 ± 12% to 29 ± 12% in DTPA and from 21 ± 15% to 24 ± 12% in DMSA. Initial Doppler ultrasonography performed in 35 patients detected an increased resistive index in 10 (29%). In the remaining patients with a normal resistive index, ureteral urinary jet was observed, indicating partial obstruction. The high frequency of renal function impairment detected by DTPA and of tubulointerstitial damage detected by DMSA as well as the slight amelioration of unilateral renal function after relief of obstruction suggest that scintigraphy assessment may help evaluate the unilateral percentage of renal function and monitor renal function recovery when it occurs. The presence of a urinary jet detected by Doppler ultrasonography further indicates the severity of obstruction and the recovery prognosis.

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- Urinary tract obstruction
- Obstructive calculi
- DTPA and DMSA scans
- Resistive index
- Doppler ultrasonography

Introduction

The presence of renal or ureteral calculi may cause urinary tract obstruction, which may or may not lead to loss of renal function. How long a human kidney will tolerate obstruction and still recover function is unknown (1). The return of renal function after relief of ureteral obstruction has been studied in dogs, rats and rabbits (2). In animals, the recovery is proportional to the duration and degree of obstruction and there is essentially no return of renal function after six weeks (3,4). The mechanisms postulated for permanent renal function impairment are elevated ureteral pressure and decreased renal blood flow, which may lead to cellular atrophy and necrosis (3,4).

In humans, many investigators have observed recovery of renal function after the relief of urinary tract obstruction caused by calculi or iatrogenic ureteral ligation lasting

28 to 348 days (1,2,5,6). The evidence about the improvement of renal function in the affected kidney was based both on an intravenous pyelogram and a radioisotope renogram (2).

The reason for the different results obtained in experimental and clinical studies is unknown but probably the complete occlusion of the urinary tract produced by ureteral ligation in animals is not comparable to the incomplete occlusions (even with nonfunctioning kidneys) that are more likely to occur in humans (6).

Although the conventional diagnosis of urinary tract obstruction is based on the intravenous pyelogram, other methods can be used for the evaluation of patients with hydronephrosis (7).

Radioisotope scans have been established as a routine method for the evaluation of individual renal function (1,6,8). Renograms using technetium labeled (^{99m}Tc)-diethylene triamine pentaacetic acid (DTPA) are used to assess the degree of obstruction and to quantify unilateral renal function (8). Scintigraphy using ^{99m}Tc-dimercaptosuccinic acid (DMSA) detects the presence of scars resulting from tubulointerstitial damage, and determines unilateral renal function as well.

Finally, Doppler ultrasonography has been reported to be able to distinguish between obstructive and non-obstructive pyelocaliectasis (9,10). It has also been suggested that severe urinary obstruction may cause a decrease in blood flow and an increase in renal vascular resistance (11). Doppler measurement of the resistive index can detect these alterations. The presence of a ureteral urinary jet suggests whether or not the obstruction is partial or complete.

Therefore, scintigraphy assessment and Doppler ultrasonography may provide a better way of monitoring renal function in patients with obstructive urinary calculi.

The aim of the present study was to evaluate renal function in patients with unilateral obstructive urolithiasis by DTPA and DMSA scans and Doppler ultrasonography before and after the relief of obstruction.

Material and Methods

Patients

The study group consisted of 47 patients (12 males and 35 females) presenting with unilateral renal or ureteral calculi and urinary tract obstruction (hydronephrosis) detected by an intravenous pyelogram (37 patients) and/or Doppler ultrasonography (35 patients). Only patients presenting normal renal function detected by creatinine clearance were enrolled in the study. Previous urinary tract infection and surgical procedures were considered as exclusion criteria.

Written consent to participate in the study was obtained from each patient, and the study was approved by the Ethics Committee of Universidade Federal de São Paulo. After an initial clinical evaluation, all 47 patients were submitted to both DTPA and DMSA scans. A possible association of the presence of unilateral functional deficit with calculus size, duration of obstruction and calculus localization was determined. The obstruction period was defined as the time from the date of the radiological diagnosis of obstruction by an intravenous pyelogram and/or ultrasonography to the date of the first scintigraphic evaluation.

The scans were repeated 6 months after relief of obstruction in 35 patients. Procedures for relief of obstruction included extracorporeal shock wave lithotripsy (ESWL) in 9, percutaneous nephrolithotomy (PN) in 7, ureterolithotomy (URE) in 5, nephrectomy in 5, ESWL + URE in 2, endoscopy procedure (ENDO) in 1 patient, ESWL + ENDO in 1 and calculus elimination in 5. These procedures were indicated according to calculus size and localization.

Doppler ultrasonography was also repeated 6 months after relief of obstruction in 21 patients.

Scintigraphy assessment

^{99m}Tc-DTPA. The exam was performed using an Elscint Apex SPX gamma camera equipped with a low energy and high resolution collimator. On the day of the exam, the patients drank 600 ml of water before radioisotope injection. The radioligand dose was 185 MBq (5 mCi) administered intravenously. The bladder was emptied immediately before the exam and the patients were then positioned with the gamma camera in contact with their back. Sequential images were acquired and fed to the computer for 30 min. Furosemide (Lasix) was administered intravenously for 20 min at the dose of 40 mg.

The normal value for percent renal function was considered to be 50 ± 6% (12). A unilateral deficit was defined for values below this percentage.

^{99m}Tc-DMSA. Patient preparation and equipment utilized were as described above. The radioligand dose was 185 MBq (5 mCi) administered intravenously. Images were obtained after 6 h with the gamma camera in posterior right, left and oblique projections.

The normal value for percent renal function was considered to be 50 ± 5% (13). A unilateral deficit was defined for values below this percentage. The presence of scars was defined by the absence of normal radioligand uptake.

Doppler ultrasonography

The exam was performed with an Ultramark 9 model color Doppler ultrasonography apparatus using a convex transducer. The transducer was placed at the corticomedullary junction of the kidney (arcuate arteries) or along the border of the medullary pyramids, corresponding to the area of interlobar arteries. The renal resistive index (RI) was calculated according to the formula: RI = (peak systolic velocity - end diastolic velocity)/(peak systolic velocity). An RI value of 0.70, usually considered as the upper limit of normality in adult kidneys (11), was utilized in the present study. Doppler ultrasonography also detects the presence or absence of a ureteral jet (14). The presence of partial or complete obstruction is observed by ultrasonography with the presence or absence of the urinary jet.

Statistical analysis

Statistical analysis of the association tables was performed using the chi-square test. The Wilcoxon test was used to compare results obtained pre- and post-relief of obstruction. Statistical significance was defined by $P<0.05$.

Results

The study was conducted on 47 patients (35 females and 12 males), aged 43 ± 13 years (X ± SD) (range, 20 to 68 years). The period of obstruction (see Methods) ranged from 1 to 41 months, with a mean value of 6 ± 8 months (X ± SD). The long period of time before performing the scan was due to the fact that many patients were referred by other services in which, for some reason, they could not be submitted to procedures for relief of obstruction.

The size of the calculi was evaluated through radiological reports and ranged from 0.7 to 4.5 cm, with an average of 1.9 ± 1 cm (X ± SD). The calculi were localized in the kidney in 24 cases and in the ureter in 23 cases. There was no significant association between renal or ureteral localization of calculi and unilateral functional deficit as determined by both DTPA and DMSA (Tables 1 and 2).

The initial DTPA evaluation showed some degree of percent renal function (18, 29 and 30%) in 3/11 patients who had presented previous renal exclusion by an intravenous pyelogram.

The initial scintigraphic evaluation by DTPA, as shown in Table 1, revealed that

68% (32/47) of the patients presented unilateral renal deficit. A calculus size between 1.1 and 2 cm showed significant association ($P<0.05$) with functional deficit on DTPA. As shown in Table 1, no significant association was found between functional deficit on DTPA and duration of obstruction. Table 2 shows the results of the initial scintigraphic evaluation by DMSA. A unilateral renal deficit was detected by DMSA in 66% (29/44) of the patients. As shown in Table 2, no significant association between functional deficit on DMSA and calculus size or duration of obstruction was found in either scan.

Table 1. Association between unilateral functional deficit and calculus size, duration of obstruction and calculus localization by ^{99m}Tc-diethylene triamine pentaacetic acid (DTPA) scintigraphy.

	Without deficit	With deficit	Total
Calculus size (cm)			
0.5-1.0	5	5	10
1.1-2.0	4	21*	25
>2.0	6	6	12
Total	15	32	47
Duration of obstruction (months)			
≤3	7	13	20
>3	8	19	27
Total	15	32	47
Calculus localization			
Renal	11	13	24
Ureteral	4	19	23
Total	15	32	47

*P<0.05 (chi-square test).

Table 2. Association between unilateral functional deficit and calculus size, duration of obstruction and calculus localization on ^{99m}Tc-dimercaptosuccinic acid (DMSA) scintigraphy.

	Without deficit	With deficit	Total
Calculus size (cm)			
0.5-1.0	5	5	10
1.1-2.0	6	18	24
>2.0	4	6	10
Total	15	29	44
Duration of obstruction (months)			
≤3	8	12	20
>3	7	17	24
Total	15	29	44
Calculus localization			
Renal	9	13	22
Ureteral	6	16	22
Total	15	29	44

Relief of obstruction by special procedures or calculus elimination was performed in 35 patients. Only those whose initial DTPA detected unilateral functional deficit (24/32) are shown in Table 3. After relief of obstruction, there was a significant increase in mean percent renal function in the affected kidney compared to the initial one detected by DTPA (29 ± 12 *vs* $25 \pm 12\%$, $P<0.05$). The mean difference was $4.6 \pm 8\%$. However, individual differences in renal function for each patient showed increases from 1 to 30%. In DMSA evaluation, after relief of obstruction there was a significant increase in mean percent renal function in the affected kidney compared to the initial one (24 ± 12 *vs* $21 \pm 15\%$, $P<0.05$). The mean difference was $2 \pm 4\%$. Individual differences in renal function for each patient showed increases from 2 to 9%.

RI was elevated in 10 of the 35 patients submitted to Doppler ultrasonography (Table 4). Five of these 10 patients exhibited a decline of RI after relief of obstruction. Of the remaining 5, 3 were submitted to nephrectomy and 2 are still waiting for procedures for relief of obstruction that were indicated according to calculus size and localization (ESWL and PN).

The presence or absence of a ureteral urinary jet was further determined in 22 of 25 patients presenting with normal RI. The presence of a urinary ureteral jet was observed in 86% (19/22) of patients. Of the 7 patients without a urinary ureteral jet, 3 showed no recovery of renal function on the affected side after relief of obstruction, 2 were submitted to nephrectomy and 2 are still waiting for a procedure.

Discussion

Although the intravenous pyelogram is

the standard method for the evaluation of urinary tract obstruction, it is a poor indicator of quantitative functional differences between the two kidneys.

Radionuclide imaging, with its ability to assess individual renal function, represents a reliable tool for the evaluation of unilateral renal function pre- and post-relief of obstruction.

In the present study, a DTPA scan detected a unilateral functional deficit in 68% (32/47) of the patients with obstructive urinary calculi and a DMSA scan demonstrated it in 66% (29/44). DTPA was also able to detect the presence of some degree of renal function even in patients with functional renal exclusion by intravenous pyelogram, as also previously suggested by other investigators (1,2,15,16).

The factors that may contribute to loss of renal function in patients with obstructive calculi are not yet clearly understood. We suggested that calculus size, duration of obstruction and calculus localization would affect renal function. Since associated urinary tract infection could also impair renal function, patients with urinary tract infection were excluded from the present analysis. Thus, the high occurrence of renal functional deficit revealed by DMSA in the pres-

Table 3. DTPA and DMSA evaluation: percent renal function (%) and renal function difference (≠) before (Pre) and after (Post) relief of obstruction and renal function (creatinine clearance), calculus localization and procedure for relief of obstruction.

Patients	DTPA Renal function			DMSA Renal function			Creatinine clearance	Calculus localizaton	Procedure
	Pre (%)	Post (%)	≠	Pre (%)	Post (%)	≠	Pre		
1	0	15	15	1	6	5	71	renal	PN
2	0	30	30	0	8	8	101	ureteral	URE
3	0	0	-	0	0	0	96	ureteral	URE
4	0	-	-	0	-	-	89	ureteral	Nx
5	0	-	-	0	-	-	90	renal	Nx
6	0	-	-	0	-	-	90	ureteral	Nx
7	0	-	-	0	-	-	60	renal	Nx
8	10	14	4				-	ureteral	URE
9	18	19	1	12	16	4	79	ureteral	ESWL/URE
10	18	20	2	11	20	9	80	ureteral	ESWL
11	18	33	15	13	16	3	75	renal	ESWL
12	19	18	-1	9	8	-1	89	ureteral	URE
13	26	31	5	32	26	-6	89	ureteral	PN
14	27	32	5	20	20	0	87	ureteral	CV
15	28	35	7	11	15	4	60	ureteral	ESWL
16	29	33	4	37	33	-4	60	renal	PN
17	32	28	-4	31	31	0	110	renal	ESWL
18	36	-	-	0	-		86	renal	Nx
19	40	40	-	38	40	2	90	ureteral	ESWL/URE
20	40	40	-	46	40	-6	100	renal	PN
21	41	34	-7	30	30	0	70	ureteral	PN
22	41	47	6	39	46	7	84	ureteral	URE
23	42	46	4	37	45	8	-	ureteral	ESWL
24	43	46	3	50	54	4	87	ureteral	CV
X ± SD	25 ± 14	29 ± 12*	4.6 ± 8	21 ± 15	24 ± 14*	2 ± 4	84 ± 13		

Procedures for relief of obstruction included: URE, ureterolithotomy; ESWL, extracorporeal shock wave lithotripsy; PN, percutaneous nephrolithotomy; Nx, nephrectomy. Patients 14 and 24 voided the calculi (CV). *P<0.05 *vs* pre (Wilcoxon test).

ent series further suggests that tubulointerstitial damage was due to the presence of calculi and/or obstruction.

In the present study, a calculus size between 1.1 and 2 cm was significantly associated with functional deficit as evaluated by DTPA but not by DMSA. The fact that calculi even larger than 2 cm were not associated with functional deficit might have been ascribed to the smaller number of patients in this group. Nevertheless, there are no accurate data in the literature addressing the influence of calculus size on renal functional deficit.

Table 4. Doppler ultrasonography: resistive index (RI) pre- and post-relief of obstruction, presence of urinary jet and percent renal function.

Patients	RI		Urinary jet	Renal function (%)	
	Pre	Post		Pre	Post
1	0.50		ND	54	
2	0.55		ND	41	
3	0.55	0.58	+	48	46
4	0.55	0.57	+	52	52
5	0.56	0.52	+	49	52
6	0.56		+	51	
7	0.57	0.60	+	47	52
8	0.57	0.62	-	19	18
9	0.59		+	41	
10	0.59	0.68	ND	0	30
11	0.59	0.51	+	49	48
12	0.59	0.55	+	27	32
13	0.59	0.64	+	52	50
14	0.60	0.58	+	42	46
15	0.60		+	41	
16	0.62		+	47	
17	0.62	0.60	+	26	31
18	0.62	0.52	+	41	34
19	0.63	0.60	+	41	47
20	0.64		+	29	
21	0.65		-	30	
22	0.66	0.52	-	40	40
23	0.68	0.56	+	10	14
24	0.68		+	32	
25	0.69	0.65	+	43	46
26	0.70	0.63	ND	32	28
27	0.71	0.60	+	0	15
28	0.72	0.55	+	51	55
29	0.72		-	0*	
30	0.75	0.65	-	40	40
31	0.76		ND	0	
32	0.76	0.70	ND	0	0
33	0.78		-	0*	
34	0.81		ND	36*	
35	0.81		-	27	

*Patients submitted to nephrectomy. +: presence of urinary jet; -: absence of urinary jet; ND: not determined.

There is no consensus concerning the relationship between duration of obstruction and renal function impairment. Although small series have observed recovery of renal function with periods of obstruction varying between 46 and 348 days (1,16,17), most of the clinical studies suggest a maximum period of approximately 3 months during which some improvement may occur (2,5,6). We did not observe a larger number of patients with functional deficit after a longer period of obstruction exceeding 3 months.

The localization of the ureteral or renal calculi was also not associated with the presence of functional deficit in either scan. Data regarding the localization of calculi and their potential influence on renal functional impairment are also scarce.

Another important advantage of both scans is to monitor the renal function recovery after relief of obstruction.

It has not been established how much of a recovery can be considered good enough. According to Lupton and Testa (18), increases of more than 5% are significant. In the present study, a significant increase of 4.6% in mean unilateral renal function was observed after relief of obstruction. Individual results indicated increases from 1 to 30%. These data are in accordance with those described by others who reported increases in renal function of 2 to 40% (19,20).

Regarding the DMSA results, a significant 2% increase in mean unilateral renal function (range, 1 to 9%) was observed after relief of obstruction. Some investigators have reported increases up to 35%, but the number of patients in those series was rather small (21), and some even reported no recovery at all (22).

Doppler ultrasonography by determining RI should be able to discriminate between obstructive and non-obstructive pyelocali-

ectasis (9,10,11). In the present series, only 29% (10/35) of the patients presented an elevated RI. However, several investigators (9,11,23) have suggested that normal RI may occur in cases of partial obstruction. The presence of a urinary jet detected in 86% (19/22) of patients with normal RI further suggests that the obstruction was not complete. All of these patients exhibited some level of function recovery or at least did not show worsened renal function of the affected side after relief of obstruction. In contrast, of the 7 patients without a urinary jet, a fact indicating severe obstruction, 3 did not ameliorate renal function, 2 were submitted to nephrectomy and the other 2 are still waiting for procedures for relief of obstruction that were indicated according to calculus size and localization (ESWL and PN). These data suggest that the severity of obstruction can be the most important factor contributing to renal impairment.

Thus, although there is no rigid algorithm for the evaluation of patients with obstructive urinary calculi, the combination of all of these methods should be useful for the assessment of quantitative unilateral renal function, tubulointerstitial damage and severity of obstruction, and for the indication of the best procedure for relief of obstruction. In addition, these methods can better monitor the renal function recovery in these patients.

References

1. Graham JB & Buffalo MD (1962). Recovery of kidney after ureteral obstruction. *Journal of the American Medical Association*, 181: 993-994.
2. Better OS, Arieff AI, Massry SG, Kleeman CR & Maxwell MH (1973). Studies on renal function after relief of complete unilateral ureteral obstruction of three months duration in man. *American Journal of Medicine*, 54: 234-240.
3. Gillenwater JY, Westervelt Jr FB, Vaughan Jr ED & Howards SS (1975). Renal function after release of chronic unilateral hydronephrosis in man. *Kidney International*, 7: 179-184.
4. Gillenwater JY (1986). The pathophysiology of urinary obstruction. In: Walsh PC, Gittes RF & Perlmutter AD (Editors), *Campbell's Urology*. WB Saunders, Philadelphia, 499-532.
5. Lewis HY & Pierce JM (1962). Return of function after relief of complete ureteral obstruction of 69 days' duration. *Journal of Urology*, 88: 377-379.
6. Shapiro SR & Bennett A (1976). Recovery of renal function after prolonged unilateral ureteral obstruction. *Journal of Urology*, 115: 136-140.
7. O'Reilly PH, Shields RA & Testa HJ (1986). Renography. In: O'Reilly PH, Shields RA & Testa HJ (Editors), *Nuclear Medicine in Urology and Nephrology*. Butterworths, London, 9-25.
8. Kelleher JP, Dave SM, Cunningham DA, Snell ME & Witherow RO'N (1991). Sequential renography in acute urinary tract obstruction due to stone disease. *British Journal of Urology*, 67: 125-128.
9. Platt JF, Rubin JM, Ellis HM & DiPietro MA (1989). Duplex Doppler US of the kidney: differentiation of obstructive and non-obstructive dilatation. *Radiology*, 171: 515-517.
10. Platt JF, Rubin JM & Ellis HM (1989). Distinction between obstructive and non-obstructive pyelocaliectasis with duplex Doppler sonography. *American Journal of Roentgenology*, 153: 997-1000.
11. Shokeir AA, Provoost AP & Nijman RJM (1997). Review: resistive index in obstructive uropathy. *British Journal of Urology*, 80: 195-200.
12. Taylor A (1999). Radionuclide renography: A personal approach. *Seminars in Nuclear Medicine*, 29: 102-127.
13. Piepsz A, Blaufox MD, Gordan I, Granerus G, Majd M, O'Reilly P, Rosenberg AR, Rossiergh MA & Sixt R (1999). Consensus on renal cortical scintigraphy in children with urinary tract infection. *Seminars in Nuclear Medicine*, 29: 160-174.
14. Begun FP, Foley WD & Peterson A (1997). Patient evaluation: laboratory and imaging studies. *Urologic Clinics of North America*, 24: 97-116.
15. Buck AC, MacLeod MA & Blacklock NJ (1980). The advantages of ^{99m}Tc DTPA in dynamic renal scintigraphy and measurement of renal function. *British Journal of Urology*, 3: 174-185.
16. Okubo K, Susuki Y, Ishitoya S & Arai Y (1998). Recovery of renal function after 153 days of complete unilateral ureteral obstruction. *Journal of Urology*, 160: 1422-1423.
17. Earlan RI (1964). Recovery of renal function after prolonged ureteric obstruction. *British Journal of Urology*, 2: 58-62.
18. Lupton EW & Testa HJ (1992). The obstructive diuresis renogram: an appraisal of the significance. *Journal of Urology*, 147: 981-998.
19. Mahmoud AH, Elgazzar AH, Nilsson TEG & Abdel-Daymen HM (1991). Silent obstruction after extracorporeal piezoelectric lithotripsy. *Clinical Nuclear Medicine*, 16: 162-164.
20. Stage KH & Lewis S (1981). Pre- and postoperative evaluation of renal function in patients with staghorn calculi utilizing quantitative renal scanning. *Urology*, 17: 29-32.
21. Chisholm GD, Chibber PJ, Wallace DMA, Hargreave TB & Merrick MV (1982). DMSA scan and the prediction of recovery in obstructive uropathy. *European Urology*, 8: 227-230.
22. Balbay MD, Varoglu E, Devrim H, Sahin A, Atan A, Ergen A & Remzi D (1997). Quantitative evaluation of renal parenchymal mass with ^{99m}technetium dimercapto-succinic acid scintigraphy after nephrolithotomy. *Journal of Urology*, 157: 1226-1228.
23. Chen JH, Liu SP & Chiu TY (1993). Renal hemodynamics in patients with obstructive uropathy evaluated by duplex Doppler sonography. *Journal of Urology*, 150: 18-21.