Volume Expansion Diuretic Renal Scan in Urinary Tract Obstruction

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The diuretic renal scan is used to differentiate the obstructed dilated urinary system from the nonobstructed dilated system. The technique, however, has a false-positive and indeterminate rate of 10%–15%. This usually is due to variables such as the degree of dilatation of the pelvicalyceal system or ureter, the degree of bladder distention, the diuretic dose, and the state of hydration. We developed the volume expansion diuretic renal scan (VEDRS) to overcome these variables and to improve the accuracy of the technique. Twelve patients who had obstructive patterns on the diuretic renal scan were evaluated. Ten patients were shown to be dilated but not obstructed. Two patients were confirmed as obstructed. This technique improves the accuracy of the diuretic renal scan.

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Diuretic radionuclide renal scans are a modification of conventional renography, which utilizes the intravenous injection of a diuretic to distinguish dilated, nonobstructive hydronephrotic systems from those with significant mechanical obstruction (*1–3*). However, ~10%–15% of patients have indeterminate results or showed delayed clearance of tracer indicating significant obstruction (*2,4,5*), but without deterioration in renal function over a 12-mo period. The major reasons for this are poor renal function, markedly dilated systems often postpyeloplasty, and vesicoureteric reflux. There are also several physiologic variables associated with diuretic stress renal scans, which will alter the shape of the clearance curves, in particular the degree of bladder distention, the dose of diuretic, the method of administration, and the state of hydration (*1,3,6*). A poorly hydrated patient may show significant delay of tracer on diuretic stimulus and, thus, appear obstructed.

We developed the volume expansion diuretic renal scan (VEDRS) in an attempt to overcome these problems. The basic principles were to ensure adequate hydration and to stress the urinary system over a longer period of time by inducing a saline diuresis before intravenous administration of diuretic.

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The VEDRS method demonstrated nonobstructive dilated systems in nine children and one adult in whom the standard diuretic clearance appeared to show obstruction, and confirmed significant obstruction in two patients with indeterminate results.

MATERIALS AND METHODS

There were 11 children (six male and five female) average 6 mo to 15 yr of age (mean 5.6 yr). One adult male aged 59 yr was also studied. All patients were normotensive and had normal serum creatinine. Twenty-two renal units and four dilated ureters were evaluated by this method.

The patients were told to drink fluids prior to their attendance at the Department of Nuclear Medicine. An i.v. infusion of 0.9% sodium chloride was administered at a rate of 360 ml/m^2 over 30 min prior to the scan. This solution and volume was used because it causes a saline diuresis in normally hydrated patients and is the initial parenteral fluid volume given to improve circulation and initiate rehydration in dehydrated patients at The Children's Hospital, Sydney. Following this fluid load a renal scan using technetium-99m diethylenetriaminepentaacetic acid ([^{99m}Tc]DTPA) at a dose of 4 mBq/kg was given intravenously. Sodium chloride 0.225% and 3.75% dextrose was continued throughout the study at maintenance levels, based on the age and body weight of the patient (e.g., 2–8 yr, 60–80 ml/kg/day). All patients were scanned in the supine position using a large field-of-view gamma camera* and high-resolution parallel hole collimator. The field of view covered kidneys and bladder. The gamma camera was interfaced to a dedicated computer† on which a differential renal analysis was collected. The data collection

protocol was 40 1-sec frames followed by 62 20-sec frames, both in 64 × 64 matrix.

Thirty minutes after initiation of the scan, if there was adequate filling of the pelvicalyceal system with tracer, the patient was asked to void. Furosemide at a dose of 1 mg/kg was then given intravenously. A further dynamic computer acquisition of 30 × 30 sec frames proceeded in a 64 × 64 matrix. Using a joystick, regions of interest (ROIs) were placed around both kidneys with a background region around each kidney for calculation of differential function. Time-activity curves were displayed and the differential function was calculated up to the point of excretion. Similar ROI were placed around both kidneys and time-activity curves of the diuretic washout phase generated. These were evaluated using a monoexponential curve fitted to the maximum slope and a half-time clearance (HTC) generated. If ureters were dilated the ROI were placed as close as possible to the site of obstruction. At the end of the diuretic study a postvoid image was taken. Urine volume postfurosemide was not calculated.

RESULTS

The mean HTC in the normal renal units was 6.0 min with an s.d. of 3.1 min. The standard diuretic renal scan was considered abnormal if the half-time clearance was >15.3 min ($\bar{x}$ + 3 s.d.). The mean half-time clearance for VEDRS in the normal renal units (standard diuretic renal scan half-time clearance <15.3 min) was 3.9 min with an s.d. of 2.1 min. VEDRS was considered abnormal if the half-time clearance was >10.2 min ($\bar{x}$ + 3 s.d.).

The standard diuretic renal scan in 11 patients showed persisting dilatation of the pelvicalyceal systems or ureters, however, there was no change in renal function over a period of 1 yr. There were 15 dilated pelvicalyceal systems or ureters (units) that showed an obstructive diuretic clearance pattern and had a half-time clearance of >15.3 min and one borderline case with a half-time clearance of 15 min. Thirteen units showed rapid clearance within the normal range during VEDRS when diuretic was administered. Two patients (three units) showed persisting dilatation with VEDRS with a half-time clearance in an obstructive range. Both cases were confirmed to have obstruction at surgery or by interventional radiographic techniques. No complications, in particular, cardiac failure or hypertension, were observed from the intravenous fluid load during the study.

CASE REPORTS

Case 1

A 7-yr-old girl had severe left-sided hydronephrosis repaired by pyeloplasty. Postoperatively, she had a markedly dilated pelvicalyceal system (Fig. 1A–C). Preoperatively, the left kidney function was <10% and over a 6-mo period, postoperatively, this increased to 35%. Postoperatively the kidney remained large with a peripheral rim of functioning renal tissue and a large dilated pelvicalyceal system. The function of the left kidney had remained at 35% over 2 yr. Diuretic clearance curves remained abnormal with half-time clearance 28.4 min (Fig. 1D). Because of this it was uncertain whether there was persisting obstruction or whether the delayed clearance was due to poor renal function and the "reservoir" effect of a very large dilated system. After VEDRS (Fig. 1E) there was rapid washout with an HTC of 8.1 min, indicating no significant obstruction.

Case 2

A 7-yr-old boy presented with acute right-sided abdominal pain. The patient underwent appendectomy during which a right hydronephrosis was observed at surgery. Intravenous pyelogram confirmed a right hydronephrosis at pelvic-ureteral junction level. A standard diuretic renogram showed poor washout from the right kidney with half-time clearance 73.4 min and markedly dilated pelvicalyceal system. The left kidney showed a prominent renal pelvis with no dilatation of the calyces but a delayed washout with half-time clearance 22.5 min. Differential renal function was: left 48% and right 52% of total renal function. Due to the uncertainty of the patient's hydration and delayed washout on the left, a VEDRS was performed (Fig. 2A–C). The right side showed persisting marked dilatation with a washout curve in the very obstructed range and HTC 98.7 min. The left kidney, however, showed improved washout but with HTC 16.8 min (Fig. 2D). At surgery acute obstruction was found at the PUJ level on the right. The postoperative period was complicated by obstruction on the left, which was relieved by the removal of thick "sludge" material during cystoscopy and retrograde pyelography. Follow-up VEDRS (Fig. 2E) 1 mo postoperatively showed there was less dilatation of the pelvicalyceal system on the right and good washout with HTC 9.6 min. The left kidney revealed an extrarenal pelvis and good washout with HTC 5.6 min.

DISCUSSION

The diuretic renal scan is a modification of conventional renal scans using the glomerular filtration agent technetium-99m diethylenetriaminepentaacetic acid ([^{99m}Tc]DTPA). The technique utilizes the administration of an i.v. diuretic, which is based on the concept that prolonged retention and delayed clearance of radionuclide in a dilated nonobstructed system is due to a reservoir or mixing chamber effect. If the flow is increased by administration of a diuretic the urine containing tracer would leave the collecting system rapidly and be replaced by urine free of tracer. In the obstructed urinary system the capacity for washout from diuretic stress is limited and there is a delay in clearance (*1–3*). Thrall et al. (*3*) described particular patterns of the diuretic renogram in normal, dilated nonobstructed, and obstructed upper urinary tracts. However, the Thrall (*3*) criteria for obstruction is by visual inspection of the curves, and significant obstruction requires a flat response; this will only detect severe obstruction. They did not quantitate the washout rate of the tracer because

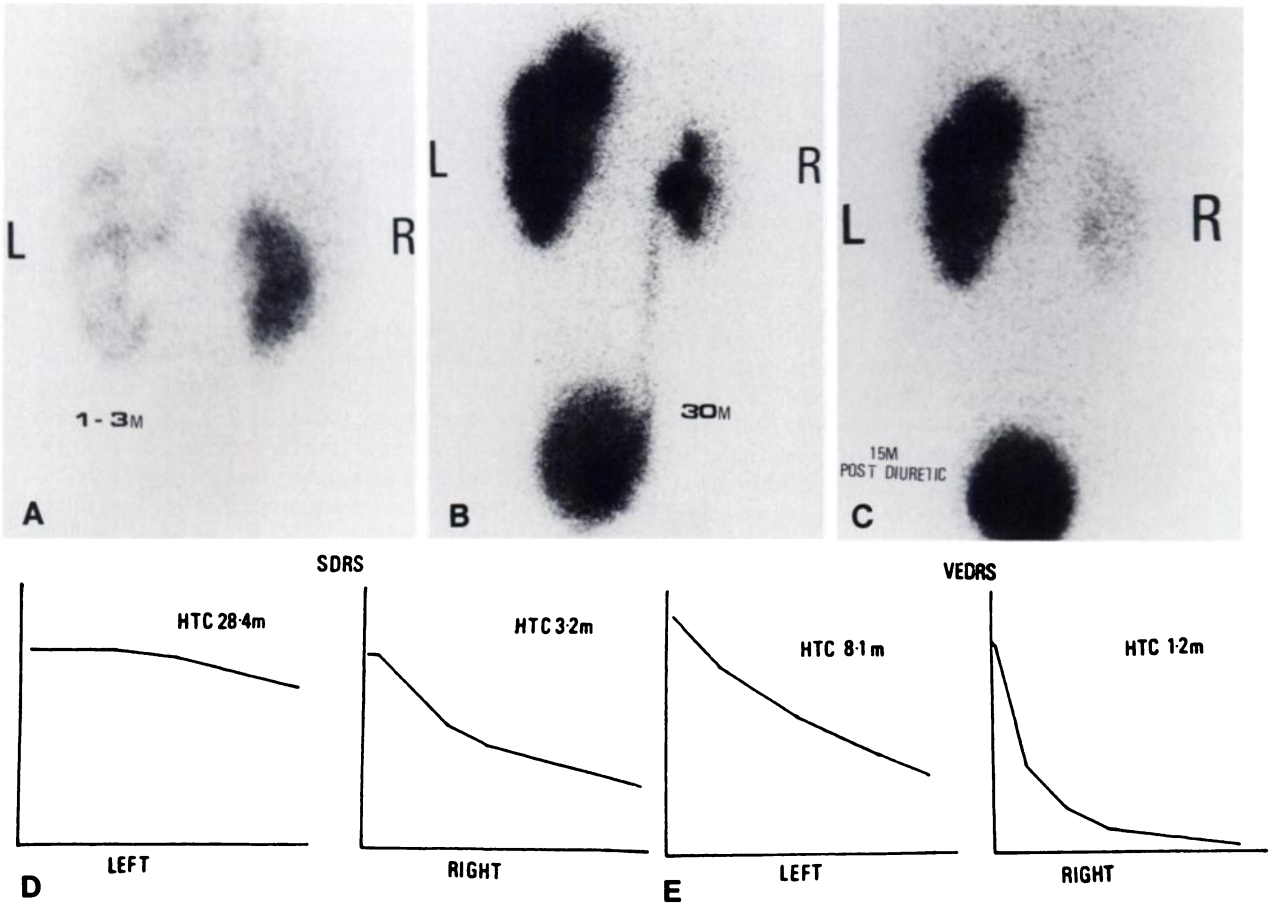

FIGURE 1
Differential renal scan with [^{99m}Tc]DTPA: Postpyeloplasty. There is persisting hydronephrosis (A) and marked dilatation of the left pelvicalyceal system at 30 min (B). The diuretic washout phase (C) shows persisting dilatation and delayed washout of tracer. During SDRS, the half-time clearance (HTC) on the left was 28.4 min (D), and on the right 3.2 min. During VEDRS the HTC on the left improved to 8.1 min (E) and on the right 1.2 min (normal <10.3 min).

there were several uncontrolled variables that would affect the slope of the washout clearance curve. Up to 15% of dilated systems visually demonstrate an intermediate or obstructive response to the diuretic (*2,4,5*). Our own experience in 194 diuretic studies (*7*) and in 650 diuretic renal scans (unpublished data), confirm the observation of Kass et al. (*4,6*), which favors interpretation of the washout curves based on calculated HTC and not the subjective appearance of the washout curve alone. Many cases of mild to moderate obstruction would be missed if one relied only on the Thrall criteria of visual inspection.

To obtain optimal conditions for interpretation, the study should be performed in a standardized manner. The variables, both anatomic and physiologic, need to be reduced. The slope of the washout curve is affected by renal functional status, the size of the dilated system, distensibility of the dilated system, bladder fullness and intravesical pressure, dose of diuretic and method of administration, vesico-ureteric reflux, and the patients state of hydration (*1,3,6*). The state of hydration is very difficult to assess. All patients are encouraged to drink fluids prior to a renal scan. O'Reilly et al. (*9*), however, found that the results were essentially equivalent when patients were studied with and without a 500-ml oral fluid load. The VEDRS is aimed at overcoming this problem. The level of renal function that will respond to a diuretic stimulus is also difficult to define; however, Kass et al (*4,6*) report that a collecting system that does not completely fill within 60 min following intravenous injection of [^{99m}Tc]DTPA or if the kidney has <20% of total renal function, the washout curve may be falsely prolonged. Even if function is poor, however, a rapid washout response to diuretic effectively excludes significant obstruction. To remove the variable of bladder fullness and elevated intravesical pressure, the patient should void prior to ingestion of the diuretic; in those patients with neurogenic or spastic bladders or vesico-ureteric reflux, a catheter should be placed in situ to drain the bladder. Kass et al. (*4*) recommend routine bladder drainage with an indwelling catheter in all patients undergoing a diuretic stress. The method and

TABLE 1

Case number	Age (yr)	Diuretic renal scan HTC (min) R	Diuretic renal scan HTC (min) L	VEDRS HTC (min) R	VEDRS HTC (min) L	
1	6	3.2	28.4	1.2	8.1	Dilatation postpyeloplasty
2	9	25	28	3.7	5.6	Bilateral megaureters
		44*	17*	2.6*	1.3*	
3	12	18	—	5.2	—	Horseshoe kidney, partial nephrectomy
4	3	9	7.7	3.7	7.2	Right megaureter
		5‡	62*	3.0*	7.7	
5	4	1.7	28	3	5.3	Left pelvic ureteral junction (PUJ) dilatation
6	8	—	17.6	—	10	Dilated right pelvicalyceal system
7	7	8	30	2.4	6.4	Dilatation PUJ postpyeloplasty
8	5	10	20	5.5	7.3	Dilatation PUJ postpyeloplasty
9	0.5	2.5	37	2.2	6.6	Left PUJ dilatation postpyeloplasty
10	59	15	3.9	3.8	3.1	Caliectasis
11	7	73.4	22.5	98.7	16.8	PUJ obstruction postoperative 1 mo
				9.6	5.6	
12	15	43	8	18.3	7	Ureteral stenosis ileal conduit

* Ureter half-time clearance (HTC).

time of diuretic administration is important. The pelvicalyceal system should be adequately filled with tracer prior to diuretic administration, otherwise this may delay the washout. Similarly, i.v. administration is essential. The time of the major diuretic response of a well functioning kidney to furosemide is within 1–5 min, even though the effect may last for several hours. Even in large capacious systems the diuretic response, although slightly longer due to a dilution effect, is within 7–10 min. Because of this, the diuretic washout phase was terminated at 15 min postdiuretic administration. Kruger et al. (*10*) and Thrall et al (*3*) also terminate the postdiuretic collection at 15 min. Even with reduction of these variables, there is still an indeterminate or false positive group of 10%–15% (*2,4,5*). This group is mainly composed of patients with very large dilated collecting systems (in otherwise well-functioning kidneys) often postpyeloplasty, and poor renal function (inadequate response to diuretic).

To evaluate this group of patients the Whitaker test has been advocated (*4,5,8*). The principle is to perfuse the upper urinary tract at a constant flow rate with diluted contrast material or saline in an antegrade manner, while simultaneously monitoring renal pelvic and bladder pressures. Theoretically, in an unobstructed dilated system the pressure is low and stable, whereas, if obstructed, there are steadily rising pressures with fluid infusion. The technique is invasive requiring percutaneous antegrade renal puncture and children usually need general anesthesia. Kass et al. (*4*) also reported limitations and an incorrect result in three of 36 kidneys examined. Because of the potential risks, the invasive nature and accuracy being similar to the diuretic renogram (*4,5,7*), the Whitaker test has not gained extensive acceptance particularly in the pediatric population.

VEDRS appears to overcome many of the physiologic variables that may alter the diuretic washout curve. The technique also offers the physiologic concept of the Whitaker test (i.e., increased flow through the urinary tract to accentuate obstruction, however, without the measurement of intrapelvic pressure). By infusing 0.9% sodium chloride prior to the scan, a saline diuresis is stimulated, which stresses the urinary system over a longer period of time than a single administration of a diuretic. In the presence of a saline diuresis, administration of a diuretic will accentuate obstructive phenomena. This technique will not be of value in patients with very poor renal function and who do not respond to a diuretic stress. No complications from the fluid load occurred during the study.

In those children described with results indicating significant obstruction but who had no deterioration of their renal function over 1 yr, the VEDRS showed a rapid washout response and, therefore, avoided more invasive procedures to determine the significance of the dilatation of their urinary systems. Similarly, in the other two patients with obstruction, the VEDRS indicated significant obstruction.

This technique improves the standard diuretic renogram and in this small number of patients described decreased the number of false-positive cases needing further investigation. A prospective study is being carried out to redefine the rates of clearance under these conditions.

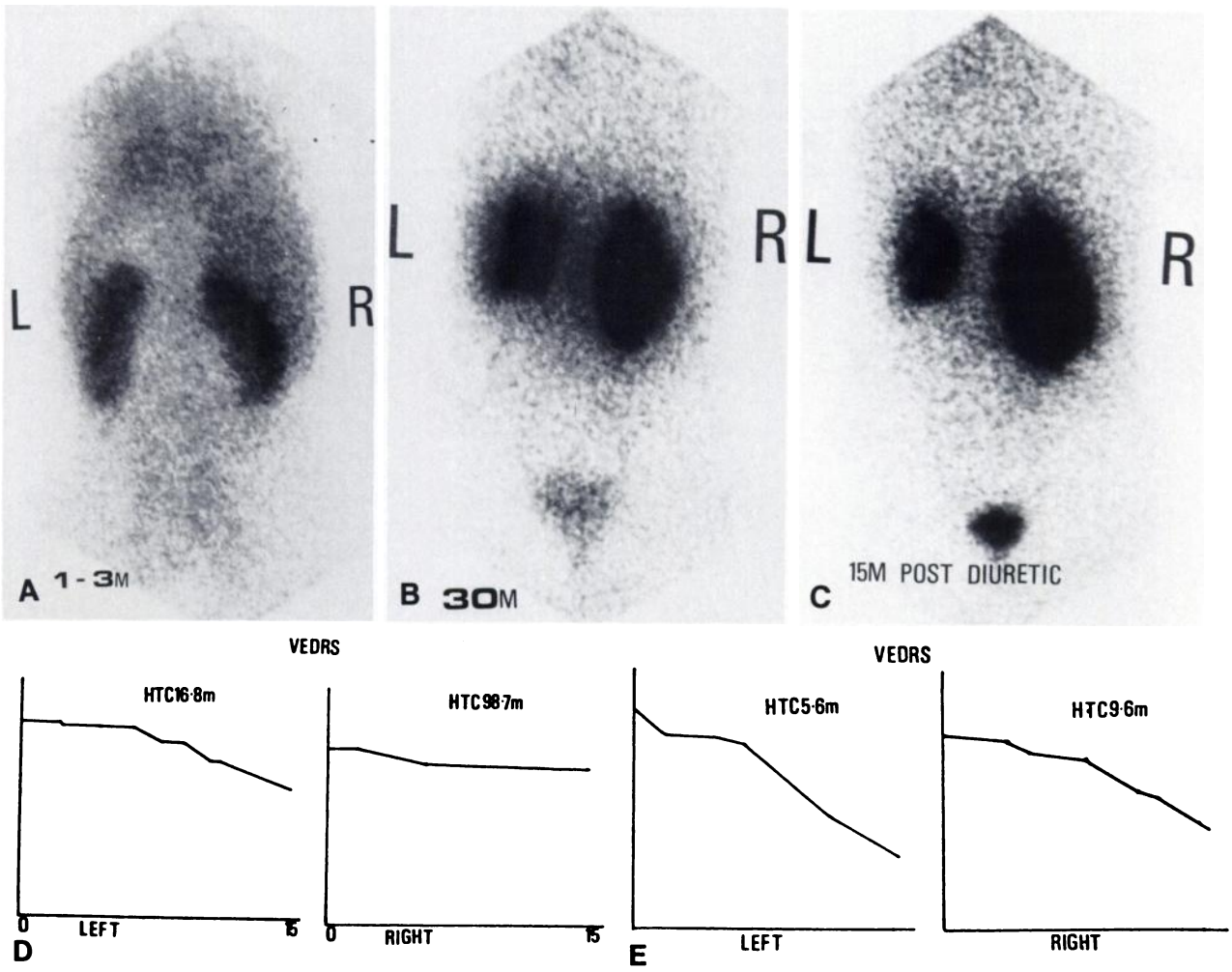

FIGURE 2
Differential renal scan with [^{99m}Tc]DTPA. There is moderate dilatation of the pelvicalyceal system on the right and a prominent renal pelvis is seen on the left (A, B). The diuretic phase (C) shows slow washout from both right and left systems. During SDRS, the half-time clearance (HTC) on the right was 73.4 min, and on the left 22.5 min. The VEDRS caused the HTC on the right to increase to 98.7 min and to decrease on the left to 16.8 min (D). One month postsurgery, a repeat VEDRS showed the HTC on the right to be 9.6 min, and on the left 5.6 min (E) (normal <10.2 min).

NOTES

* Sigma 438, Technicare Corp., Solon, OH.

† DEC 11/34 Gamma II System, Picker Int'l., Highland Hgts., OH.

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