
Volume Expanded Diuretic Renography in the Postnatal Assessment of Suspected Uretero-Pelvic Junction Obstruction

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Controversy surrounds the role of ^{99m}Tc -diethylenetriamine pentaacetic acid renography in suspected uretero-pelvic junction obstruction in early life. Accordingly, we retrospectively reviewed 18 patients (28 hydronephrotic kidneys) with a mean age of 2 mo (range: 1 wk–6 mo) who underwent a total of 36 scans using intravenous volume expansion (10 ml/kg) and furosemide diuresis (1 mg/kg). Initial scans were classified as obstructed, not obstructed or indeterminate using differential renal function, furosemide washout $T_{1/2}$ and visual assessment of tracer clearance. Those initially classified as obstructed ($n = 8$) have been surgically confirmed. In the indeterminate ($n = 6$) and nonobstructed ($n = 14$) groups, three and two kidneys, respectively, developed obstruction on progress scans. Mean follow-up in the nonsurgical patients was approximately 9 mo (range: 4–17 mo). A total of 13 kidneys had developed obstruction by renographic criteria, and to date 12 have surgical confirmation. Our data indicate that: (1) scans classified as obstructed correlate well with surgery; (2) an initial classification of indeterminate or nonobstructed does not exclude later development of obstruction; and (3) serial scans correctly stratify children with possible uretero-pelvic junction obstruction.

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The introduction of routine prenatal ultrasound has led to earlier and more frequent detection of fetal hydronephrosis. Obstruction at the uretero-pelvic junction (UPJ) is the most common cause of this condition (1).

Despite the earlier detection, the optimal postnatal investigation and management of possible UPJ obstruction remains controversial. Surgical intervention is necessary in infants with obstruction to preserve renal function and to allow maximal renal development, while in cases of nonobstructive hydronephrosis a conservative approach is adequate. However, a single test in the early postnatal

period may be inadequate since some patients with suspected UPJ obstruction will spontaneously improve and not require surgery, while others will deteriorate necessitating operative intervention (2–4).

Over the years, diuretic renography has become relatively well established as a useful procedure in UPJ obstruction (5,6). More recently, however, the value of this test in the neonatal period has been questioned (7,8). These reports, however, may have been limited by inadequate hydration, a factor that others have found to be of importance (5,9,10).

The purpose of this study is to determine the role of volume expanded diuretic renography (VEDR) in infants with possible UPJ obstruction.

PATIENTS AND METHODS

A retrospective review of 18 consecutive infants (28 hydronephrotic kidneys) referred with possible UPJ obstruction over an 18-mo period was performed. There were 16 males and 2 females ranging in age from 1 wk to 6 mo (mean age: 2 mo).

All patients met the following criteria: (1) prenatal and postnatal ultrasound demonstrating hydronephrosis and (2) either no radiologic evidence of vesico-ureteric reflux (VUR) or if VUR was present ($n = 3$), disproportionate dilatation of the renal pelvis.

On the morning of the study, oral fluids were encouraged after which 10 ml/kg of 0.9% sodium chloride solution were administered intravenously during the 30 min preceding the scan. A renal scan using ^{99m}Tc -diethylenetriamine pentaacetic acid (DTPA) was then performed. The dose used was scaled for body weight and based on an adult dose of 600 MBq (11). Posterior imaging using a large field of view gamma camera and a high-resolution, parallel-hole collimator interfaced to a DEC PDP 11/34 computer system was performed with the patient in the supine position. The image acquisition protocol was 40 1-sec frames followed by 62 20-sec frames. Intravenous furosemide (1 mg/kg) was given when visual assessment indicated maximum pelvicalyceal distention. This usually occurred at 20–30 min after ^{99m}Tc -DTPA administration. Subsequently, 60 20-sec frames were obtained and the half-time clearance following furosemide ($T_{1/2}$) was generated using a mono-exponential curve fitted to the maximum slope. Urinary bladder catheterization was only performed if VUR was known to be present. The degree of urinary bladder

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filling was monitored and post-void images were obtained if spontaneous voiding did not occur during the study. Patients were not routinely sedated.

Following the initial scan, each kidney was classified by an experienced observer as obstructed, nonobstructed or indeterminate for obstruction. Obstruction was defined as the presence of at least two of the following: (1) relative function <40%, (2) $T_{1/2}$ >15 min and/or (3) visual assessment revealed progressive tracer retention in the renal pelvis or minimal function by the kidney. In cases of suspected bilateral obstruction, interpretation was largely dependent on the $T_{1/2}$ and visual assessment. A kidney was considered nonobstructed if at least two of the following were present: (1) the relative function was in the normal range, (2) $T_{1/2}$ <10 min and/or (3) visual clearance of tracer from the renal pelvis occurred. Patients not meeting any of these criteria were indeterminate for obstruction.

A total of 36 scans was obtained. The final diagnosis was based on surgical findings (n = 12 kidneys), with histopathological correlation when available (n = 10 kidneys). In the remaining 16 kidneys, the final diagnosis was made by serial VEDR (n = 13) or progress ultrasound (n = 3). Resolution of hydronephrosis on ultrasound was considered indicative of no obstruction. In patients undergoing more than one scan (n = 12) before the final diagnosis was made, the second study was performed 1–10 mo (mean = 4 mo) after the initial scan. The mean duration of follow-up for the nonsurgical patients (n = 9) was approximately 9 mo (range: 4–17 mo). Post-pyeloplasty VEDR was performed in all but one patient, with a mean interval following surgery of approximately 3 mo (range: 2 wk–5 mo).

RESULTS

In all the kidneys initially classified as obstructed (n = 8), the diagnosis was confirmed at surgery (Table 1). The mean age at diagnosis was 11 wk (range: 1 wk–6 mo).

In the nonobstructed group (n = 14), 12 kidneys remained free of obstruction, while 2 developed surgically proven UPJ obstruction (Patients 4 and 16). The left kidney of Patient 4 was classified as nonobstructed despite the reduced relative function because of good tracer clearance and normal $T_{1/2}$. Patient 16 had a $T_{1/2}$ >15 min but was classified as nonobstructed because of significant although incomplete tracer clearance following furosemide (Fig. 1). In retrospect, this patient may have been more appropriately classified as indeterminate for obstruction in view of the incomplete washout. In the indeterminate group (n = 6), three developed changes that met our classification criteria for UPJ obstruction and so far two have undergone pyeloplasty. The remaining three kidneys were not obstructed on follow-up (Fig. 2).

In the five kidneys that developed UPJ obstruction, the mean follow-up period at the time of detection was 14 wk (range: 12–15 wk) and the mean age 5.50 mo (range: 4.50–8 mo). No documented renal function deterioration occurred during the intervening period by biochemical criteria.

TABLE 1
Patient Data and Results

Patient no.	U/S	MCU	Age	% Function	$T_{1/2}$	Stratification		Outcome (F/U period)
						Left	Right	
1	Bilat	NR	1 wk	40% Lt	>15	O	O	Lt Sx at 1 wk; Rt Sx at 11 mo
2	Bilat	NR	6 wk	50%	10–15	I	I	Rt Sx at 6 mo; Lt preSx (11 mo)
3	Bilat	NR	1½ wk	50%	<10	N	N	Lt/Rt N (U/S F/U to 12.50 mo)
4	Bilat	Bilat Gr5	5 wk	30% Lt	Rt > 15 Lt < 10	N	O	Rt Sx at 2.50 mo; Lt Sx at 5.50 mo
5	Bilat	Bilat Gr5	17 wk	30% Lt	>15	O	I	Lt Sx at 5 mo; Rt Sx at 11 mo
6	Bilat	NR	9 wk	50%	<10	N	N	Lt/Rt N (17 mo)
7	Rt	NR	6 mo	50%	>15	—	O	Rt Sx at 8 mo
8	Lt	NR	8 wk	50%	<10	N	—	N (U/S F/U at 4 mo)
9	Bilat	NR	2 wk	50%	Lt 10–15 Rt < 10	I	N	Lt/Rt N (13 mo)
10	Bilat	NR	4 mo	50%	Lt 10–15 Rt < 10	N	N	Lt/Rt N (4.50 mo)
11	Rt	NR	3 mo	50%	>15	—	O	Rt Sx at 5.50 mo
12	Lt	NR	3½ mo	50%	<10	N	—	N (U/S F/U at 4 mo)
13	Rt	NR	2 mo	0% Rt	?	—	O	Rt Sx at 3 mo
14	Rt	NR	2½ mo	50%	10–15	—	I	N (9.50 mo)
15	Bilat	NR	1 wk	50%	10–15	N	N	Lt/Rt N (11 mo)
16	Rt	NR	2 mo	50%	>15	—	N	Rt Sx at 6 mo
17	Bilat	Lt Gr3	1½ mo	50%	Lt < 10 Rt > 15	N	I	Lt/Rt N (4.50 mo)
18	Lt	NR	6 wk	35% Lt	>15	O	—	Lt Sx at 3.50 mo

VEDR = volume expanded diuretic renography; MCU = micturating cystourethrography; U/S = ultrasound (hydronephrosis); N = no obstruction; ? = calculation not possible; VUR = vesico-ureteric reflux; NR = no vesico-ureteric reflux; PreSx = awaiting surgery; Sx = pyeloplasty; I = indeterminate; — = normal with no hydronephrosis and O = obstruction (uretero-pelvic jn).

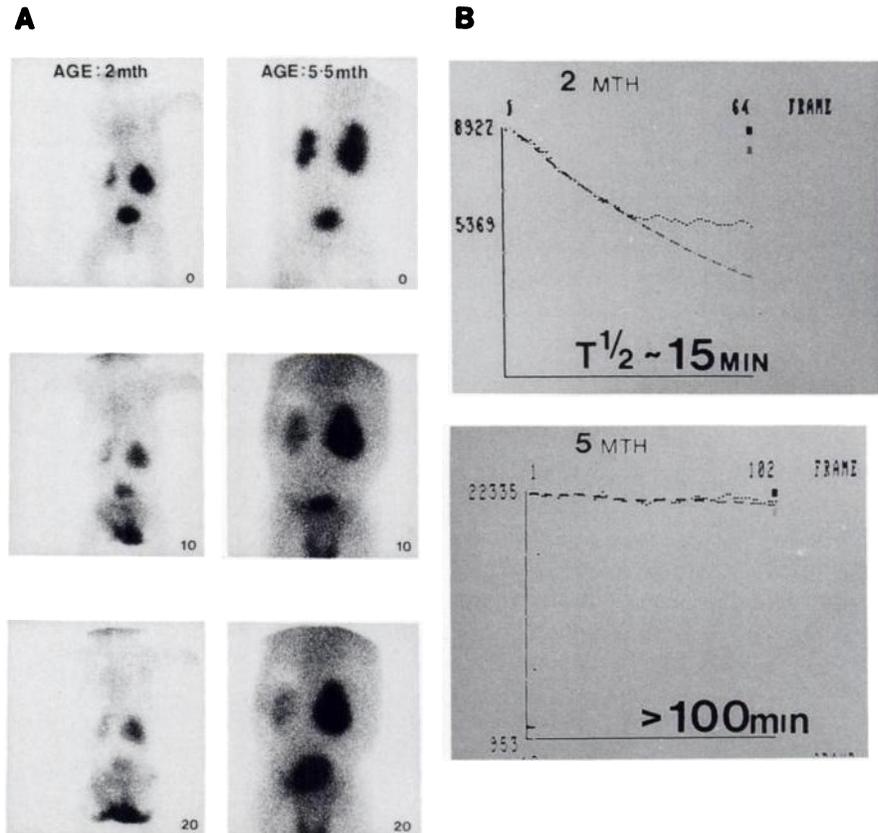


FIGURE 1. Patient 16. (A) Posterior images of studies performed at 2 and 5.50 mo of age demonstrate the development of right UPJ obstruction. (B) The post-furosemide washout curves demonstrate the deterioration in clearance from the right renal pelvis.

In this study, a total of 13 kidneys had UPJ obstruction by VEDR criteria, and so far 12 have been confirmed at surgery. All 12 kidneys exhibited gross dilatation of the pelvi-calyceal system with a narrowed, slightly tortuous UPJ adherent to the renal pelvis in the typical configuration of severe congenital UPJ obstruction. A Hynes-Anderson dismembered pyeloplasty was performed in each case. At surgery, an attempt was made to calibrate the diameter of the intact UPJ, however, none would even admit a 3-French ureteric catheter. Intrapelvic pressures were not measured during surgery. In no case was the obstruction due to compression by adjacent vessels. In 10 patients, the excised segment of renal pelvis and adjacent upper ureter were sent for histopathological examination. Histopathology of all specimens demonstrated the typical morphological changes of obstruction with marked collagen infiltration between and within the smooth muscle bundles (12,13).

All the post-pyeloplasty scans demonstrated free drainage from the operated kidneys with no evidence of persistent obstruction. However, in the patients with asymmetric renal function, the relative function only improved in one (20%), suggesting that renal damage had occurred in the other cases.

In the five patients with surgically proven unilateral UPJ obstruction, the relative renal function approximated 50% in three.

DISCUSSION

The major dilemma facing clinicians caring for newborns with a suspected UPJ abnormality is deciding whether or not obstruction is present. In this study of infants with hydronephrosis, we have found serial VEDR to be highly accurate in identifying obstructed kidneys in the first few months of life. There have been no proven false-positive diagnoses.

We have also found that the initial VEDR correctly stratified the majority of kidneys as obstructed or not obstructed. Five kidneys initially classified as nonobstructed or indeterminate did develop overt UPJ obstruction on follow-up. These reflect the phenomenon of transitional hydronephrosis whereby differential maturation of the renal collecting system and renal function can result in the development of obstruction or progressive improvement in collecting system drainage (3,14,15). We currently recommend that progress scans should be performed at approximately 6 mo of age in patients initially classified as nonobstructed or indeterminate.

Several authors have found diuretic renography unreliable in diagnosing UPJ obstruction in the newborn (7,8,16). In the early neonatal period, the diagnosis of UPJ obstruction may be difficult because of reduced renal function and impaired diuretic response. It has been proposed that in unilateral hydronephrosis the half-time clearance in the nonaffected kidney may indicate when there

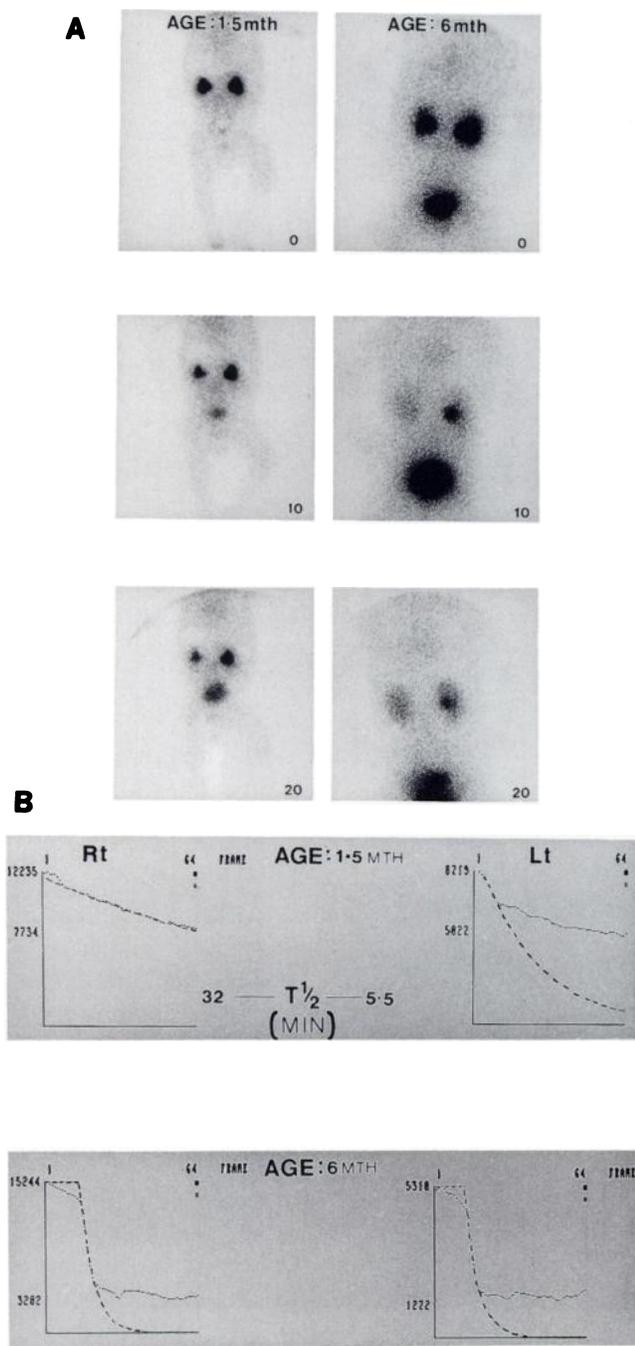


FIGURE 2. Patient 17. (A) Posterior images from studies performed at 1.50 and 6 mo of age demonstrate improved drainage from both kidneys with time. (B) The post-furosemide washout curves reflect the improved clearance.

is adequate renal functional maturity to allow accurate diuretic renographic interpretation (16). However, in the above reports, hydration was not optimized and this may partly account for their results. In our study, four patients (eight kidneys) were under 4 wk of age at the time of referral and in only one patient (two kidneys) were the kidneys classified as obstructed. UPJ obstruction was subsequently confirmed by surgery and histopathology in both kidneys (Patient 1).

It has become clear that in order to obtain maximum benefit from diuretic renography, intravenous hydration should be combined with diuretic administration in order to maximize urine output. These factors are essential in overcoming the reservoir or mixing chamber effect which may simulate obstruction in dilated, nonobstructed systems (9,10). We observed no complications from the fluid load or diuretic administration.

Our patient cohort had a significant male predominance (16 M, 2 F). Previous reviews of pediatric UPJ obstruction/dysfunction have also observed a greater incidence in males, particularly those under 1 yr of age (17-19), however, no clear explanation for this has been forthcoming.

In our study, patients did not routinely undergo urinary bladder catheterization and therefore the success of volume expansion and furosemide administration in achieving a diuresis could only be assessed by qualitative measures. Because this study was retrospective and the VEDR results impacted upon patient management, the true diagnostic accuracy of this test could not be inferred from this study. The diagnosis of UPJ obstruction was independently confirmed at surgery, but there was no surgical verification in the kidneys considered nonobstructed. However, follow-up in these patients has not demonstrated any deterioration in renal function as would be expected in untreated obstruction.

In summary, serial diuretic renography with volume expansion plays an important role in accurately identifying UPJ obstruction in the first few months of life. The initial study will correctly stratify patients with obstruction, however, in those initially classified as indeterminate or nonobstructed, follow-up is mandatory.

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EDITORIAL

Tracking the Natural History of Infantile Hydronephrosis with Diuretic Renography

Congenital anomalies of the genitourinary system have a prevalence estimated at 4-7/1000 (1). These malformations, which account for a substantial number of children with renal failure, can be reliably identified with ultrasound between 16 and 18 wk of gestational age (2). Specific anatomic diagnoses can be defined sonographically and include ureteropelvic junction (UPJ) obstruction, duplex systems with polar hydronephrosis and ureterovesical junction obstructions with megaureter (3). However, "obstruction is not a single disease process, and its outcome cannot be predicted purely by anatomic appearance" (4). Hence many of the genitourinary anomalies initially defined sonographically are susceptible to later investigation by nuclear imaging techniques.

The sensitivity of ultrasonographic diagnosis is such that a wide spectrum of degrees of hydronephrosis (HN), including cases of minimal severity, are encountered. Management of these complex disorders presents a major, unresolved clinical problem in terms of natural history, and the unsettled question of the indications for surgery (4). Consequently there is a pressing clinical need for a reliable test to assess the necessity or appropriate-

ness of surgical intervention in affected children.

A consideration of the functional significance of HN is fundamental to an understanding of the relevant diagnostic armamentarium. In the past, HN has always been considered to be pathologic. However, the condition does not necessarily worsen, and many patients have no reduction in renal parenchymal function. Up to 40% of patients after pyeloplasty for UPJ obstruction show no measurable postoperative improvement (5).

This clinical evidence for nonprogression of HN is consistent with experimental studies where surgically created ureteric obstruction is not followed universally by dilation of the kidney (6). Some have gone as far as to say that HN should be viewed as a beneficial compensatory mechanism.

It has been proposed (4) that the potential for development of HN depends on four salient factors:

1. Urinary output and flow rates during diuresis.
2. Anatomy and tightness of the obstruction.
3. Glomerular and tubular function.
4. Changes in compliance of the renal pelvis.

It should be noted that nuclear medicine techniques directly measure only Parameter 3. Parameters 1 and 2 are assessed partly and indirectly, and Parameter 4 is not estimated.

SIGNIFICANCE OF URETEROPELVIC JUNCTION (UPJ) OBSTRUCTION

This anomaly is the most common cause of prenatally diagnosed HN (7). Its etiology can be broken down into factors which may be extrinsic (vessels, bands, adventitial tissues), or intrinsic (an adynamic segment or true narrowing). Current evidence suggests that these two patterns are associated with different types of flow patterns across the UPJ and hence determine progression or equilibrium of the underlying pathology (8).

The classification of UPJ obstruction as intrinsic versus extrinsic may also be relevant to interpretation of the diuretic renogram. The test may be most reliable in the presence of moderate intrinsic obstruction, with or without additional extrinsic obstruction. In this situation, the pressure-exit flow curves will be flat so that normal flow rates are possible only when intrapelvic pressure is above normal (as is produced by the diuretic challenge). Here the slow emptying rate can be easily detected.

In mild intrinsic obstruction, the dilated pelvis may have reached a new equilibrium so it can respond to an increased flow rate by emptying normally: hence, the potential for false-negative test results. With extrinsic obstruction, the diagnosis can only be made when the kidney is overdistended.

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