

Evaluation of Differential Renal Function and Renographic Patterns in Patients with Dietl Crisis

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Abbreviations and Acronyms

CR = cortical retention
CT = computerized tomography
DR = diuretic renography
DRF = differential renal function
MAG3 = ^{99m}technetium labeled mercaptoacetyltriglycine
UPJ = ureteropelvic junction

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Study received institutional review board approval (protocol No. 5122).

Purpose: We analyzed preoperative and postoperative differential renal function and characterized the renographic findings in patients with ureteropelvic junction obstruction associated with Dietl crisis.

Materials and Methods: Patients with Dietl crisis who underwent pyeloplasty between January 2004 and December 2010 were classified by renographic presentation. Patients in group 1 were diagnosed with cortical retention, those in group 2 had an initial obstructed scan (T1/2 of 20 minutes or more and no cortical retention) and those in group 3 had an initial nondiagnostic scan (T1/2 of less than 20 minutes and no cortical retention). Renographic parameters were used to analyze each group.

Results: A total of 59 patients met criteria for study inclusion. The 13 patients in group 1 demonstrated the most significant recovery of function after pyeloplasty (mean differential renal function change 13.59%). The 38 patients in group 2 exhibited a mean differential renal function change of 43.06% (range 20% to 54.6%) and mean preoperative T1/2 of 64.31 minutes. Pyeloplasty was performed in all 8 patients in group 3 based on subsequent diagnostic scan (4 patients) or increased hydronephrosis on other imaging associated with further symptomatic episodes (4). Initial renographic patterns noted in group 3 included biphasic curves, diminished clearance after 15 minutes upright or symptoms despite nonobstructive drainage.

Conclusions: Interpretation of diuretic renography requires the assimilation of multiple parameters since patients with Dietl crisis can exhibit variability in renographic patterns due to the intermittent nature of ureteropelvic junction obstruction. Cortical retention represents a specific and pathognomic finding of acute ureteropelvic junction obstruction. With appropriate evaluation of these parameters, obstruction can be reliably diagnosed and appropriate surgical candidates chosen.

Key Words: hydronephrosis, kidney pelvis, radioisotope renography, ureteral obstruction, urologic surgical procedures

BEFORE the introduction of routine prenatal sonography congenital ureteropelvic junction obstruction most frequently presented as abdominal pain in older children.¹ Most newly diagnosed cases of ureteropelvic junction obstruction are now asymptom-

atic, with approximately 13,000 newborns diagnosed with this condition each year in the United States.² However, a minority of children escape early identification and present at an older age with intermittent unilateral flank or abdominal pain associated

with nausea and/or vomiting, otherwise known as Dietl crisis.

When sonography or CT reveals hydronephrosis in a child with abdominal pain, MAG3 diuretic renography supports the diagnosis of UPJ obstruction based on poor post-diuresis clearance of radiotracer from the hydronephrotic collecting system,³ and quantifies differential renal function.⁴ We have observed that while DRF is symmetrical in most children presenting with Dietl crisis, the DR patterns in these children may vary widely. We analyzed preoperative and postoperative DRF, and characterized the renographic findings in patients with Dietl crisis who underwent pyeloplasty for UPJ obstruction.

METHODS

We reviewed our billing records for all patients who underwent dismembered pyeloplasty (CPT code 50400) between January 2004 and December 2010. Patient medical records were reviewed for inclusion and exclusion criteria. Study received institutional review board approval.

Selection Criteria

We identified 88 patients from our billing records who were at least 3 years old and who underwent dismembered pyeloplasty (CPT code 50400) between January 2004 and December 2010. Patients were included who 1) had at least 1 episode of Dietl crisis, 2) underwent at least 1 preoperative renal sonogram or CT and 3) underwent at least 1 DR postoperatively. Dietl crisis was defined as intermittent unilateral flank or abdominal pain (corresponding to side of UPJ obstruction) with or without nausea and/or vomiting. Patients were excluded who were incidentally discovered (19 patients), had UPJ obstruction of a renal transplant (1) had previously undergone genitourinary surgery (3), presented with urinary tract infection (4), had ureterovesical junction obstruction (1) or did not have imaging available (1), including 7 patients who did not undergo postoperative followup DR.

Data Extraction

Personal health information was collected as medical record numbers, dates and names. Once the chart was reviewed, all identifiers were immediately lost to the researcher and the charts were identified based on an assigned number. The deidentified clinical information from children meeting all of these criteria was entered on specific clinical reporting forms for entry into the study database. Documentation of all relevant deidentified information, including clinical characteristics, symptoms at presentation, clinical history of disease, imaging study results and surgical procedures, was recorded.

Diuretic Renography Method/Interpretation

All DRs at our center are performed and interpreted under the direct supervision of nuclear medicine radiologists, who tailor the studies in real time according to the protocol described by Majd.⁵ Factors that may affect study results, such as hydration, degree of bladder filling and timing of diuretic administration, are controlled.

After intravenous administration of MAG3 (average 50 $\mu\text{Ci}/\text{kg}$, range 1 to 3) dynamic 15-second images are obtained (usually for 30 minutes). Uptake of radiotracer at 1 to 3 minutes after injection is used to determine the percent of contribution to total renal function of each kidney (DRF). Accumulation of the radiotracer is continuously monitored, and when the dilated system is entirely filled with radiotracer, furosemide is administered (1 mg/kg intravenously, maximum 40 mg) and dynamic images are obtained for 30 minutes. These images are used for calculation of the washout half-time of the radiotracer and its residual at 30 minutes after administration of furosemide. If the residual radiotracer is high, the percent of retained radiotracer cleared after 15 minutes of gravity assisted drainage in the upright position is calculated.

DRs are scheduled as routine, and not coinciding with the episode of pain. However, when a DR is obtained during or within 48 hours of an episode of Dietl crisis, CR of radiotracer can be seen and is pathognomonic of acute obstruction. In these cases furosemide is not administered.

The patients were divided into groups based on DR parameters. All patients in group 1 showed cortical retention and underwent early pyeloplasty. Patients in group 2 underwent early pyeloplasty when DR demonstrated an obstructed drainage pattern and/or decreased DRF. Patients in group 3 had inconclusive initial DRs that revealed a $T_{1/2}$ of less than 20 minutes. Some of these patients showed prolonged half-time on subsequent imaging or recurrent symptoms.

Statistical Methods

The data retrieved were then analyzed to evaluate the outcomes of children with a history of Dietl crisis. Statistical analysis to determine significance was performed using Student *t* test with 2-tailed distribution for a sample size of 30 cases or more and a normal distribution, while the Wilcoxon rank sum test was used for a sample size of less than 30 cases without a normal distribution. Paired Student *t* test was used to compare preoperative and postoperative observations within a group, while unpaired *t* test was used to compare preoperative and postoperative observations between different groups.

RESULTS

A total of 59 patients met study eligibility criteria. Patient characteristics were similar to previous series, including age at presentation (2.4 to 19 years) and mean age at surgery (8.55 years). There was a preponderance of males (49, 79.7%) and the majority of UPJ obstructions were on the left side (42, 71.2%). Postoperative followup ranged from 1 to 25 months (mean 4.89).

The 13 patients in group 1 who presented with Dietl crisis demonstrated retention of radiotracer in the cortex and underwent surgical repair as a result. Mean preoperative DRF in this group was 30.1%, which improved to 39.7% postoperatively, a difference that was not statistically significant ($p = 0.089$). Because of cortical retention, little or no

radiotracer filled the renal pelvis, precluding determination of half-time and drainage curve morphology. Four of these patients were evaluated via MAG3 renal scan within 48 hours of an acute episode of Dietl crisis. Although the remaining 9 patients were evaluated with diuretic renography more than 48 hours after presenting with Dietl crisis, cortical retention was still present (fig. 1). Three of the patients were lost to followup and did not have a postoperative diuretic renogram available.

The 38 patients in group 2 had a mean \pm SD DRF of $43.1\% \pm 9.4\%$ (range 20% to 54.6%). Mean \pm SD preoperative T1/2 was 64.3 ± 33.9 minutes (range 2 to 100). Of the patients 15 had such prolonged drainage that they were assigned a T1/2 of 100 minutes, corresponding to flat or rising drainage curves. The sole patient with a T1/2 of 2 minutes was deemed to have obstruction despite initially prompt drainage, since after 7 minutes progressive accumulation of isotope was seen in the kidney, resulting in a biphasic drainage curve (fig. 2). Mean \pm SD postoperative DRF was $45.0\% \pm 9.1\%$ (range 24.3% to 57.5%). The difference between preoperative and postoperative DRF was statistically significant ($p = 0.014$). All patients had a successful postoperative result, as reflected by a mean \pm SD T1/2 of 9.82 ± 7.6 minutes (range 2 to 29). Four individuals who had a postop-

erative T1/2 of more than 20 minutes had significant postoperative improvement in diuretic T1/2 of 22, 23, 28 and 29 minutes. Four patients were lost to followup and did not have a postoperative diuretic renogram available.

In the 8 patients in group 3 the initial DR obtained in the absence of symptoms did not reveal obstruction. Pyeloplasty was subsequently performed for recurrent symptoms and imaging supporting a diagnosis of intermittent UPJ obstruction. Preoperatively this group had a mean \pm SD DRF of $48.3\% \pm 4.3\%$ (range 39.9% to 53.7%) and T1/2 of 9.8 ± 5.4 minutes (3 to 16). Postoperatively the group had a mean \pm SD DRF of $50.1\% \pm 5.1\%$ (range 38.6% to 54.5%) and T1/2 of 5.9 ± 3.8 minutes (3 to 14). There was no statistically significant difference between preoperative and postoperative DRF ($p = 0.27$).

Five patients had 1 initially inconclusive DR before surgical repair, and 3 had 2 or more. Three of the 5 patients with initially inconclusive DR underwent pyeloplasty since CT at symptom recurrence showed increased hydronephrosis, and 2 underwent pyeloplasty based solely on recurrent symptoms. Of the 3 patients with 2 or more inconclusive DRs 1 underwent pyeloplasty based on CT findings of obstruction during symptom recurrence, 1 underwent

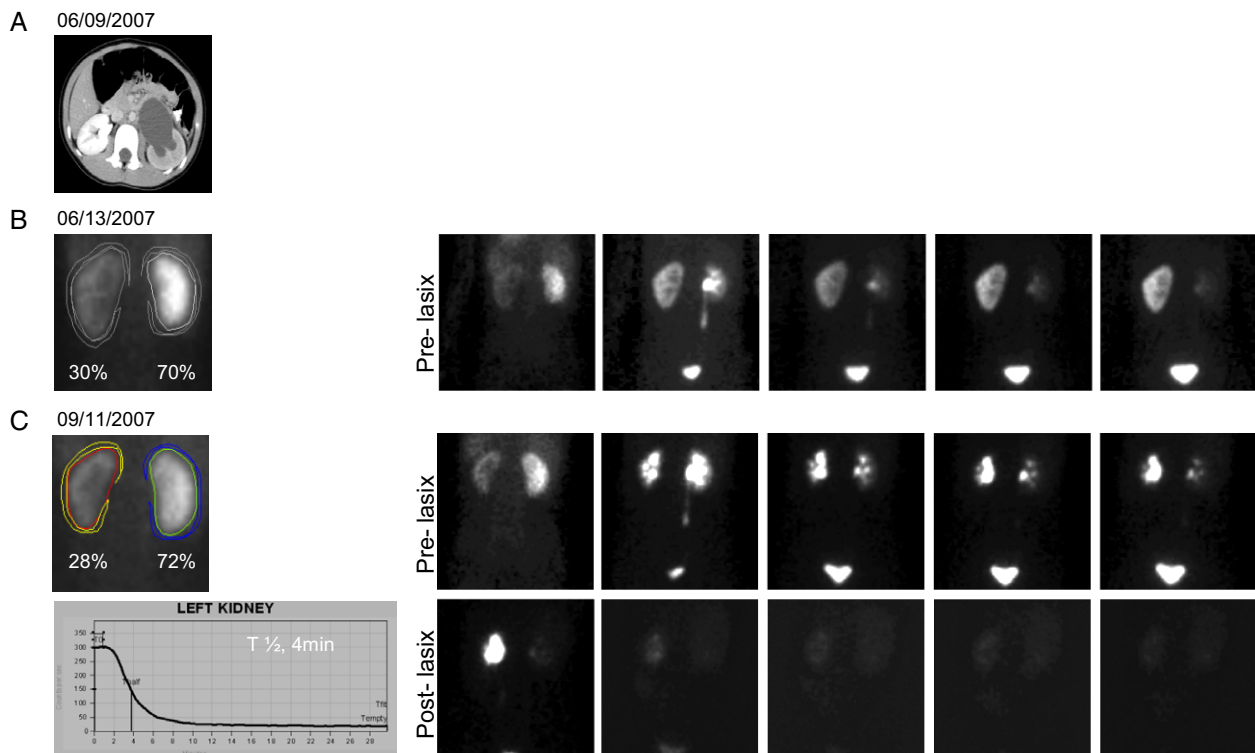


Figure 1. A, computerized tomography with intravenous contrast material reveals delayed nephrogram and significant hydronephrosis in 7-year-old girl presenting with left flank pain. B, MAG3 renogram 4 days later shows reduced differential renal function from left kidney and retention of radiotracer in left renal cortex. C, following pyeloplasty, diuretic renography demonstrates renal function is stable and post-diuresis drainage is prompt with T1/2 of 4 minutes. *lasix*, furosemide.

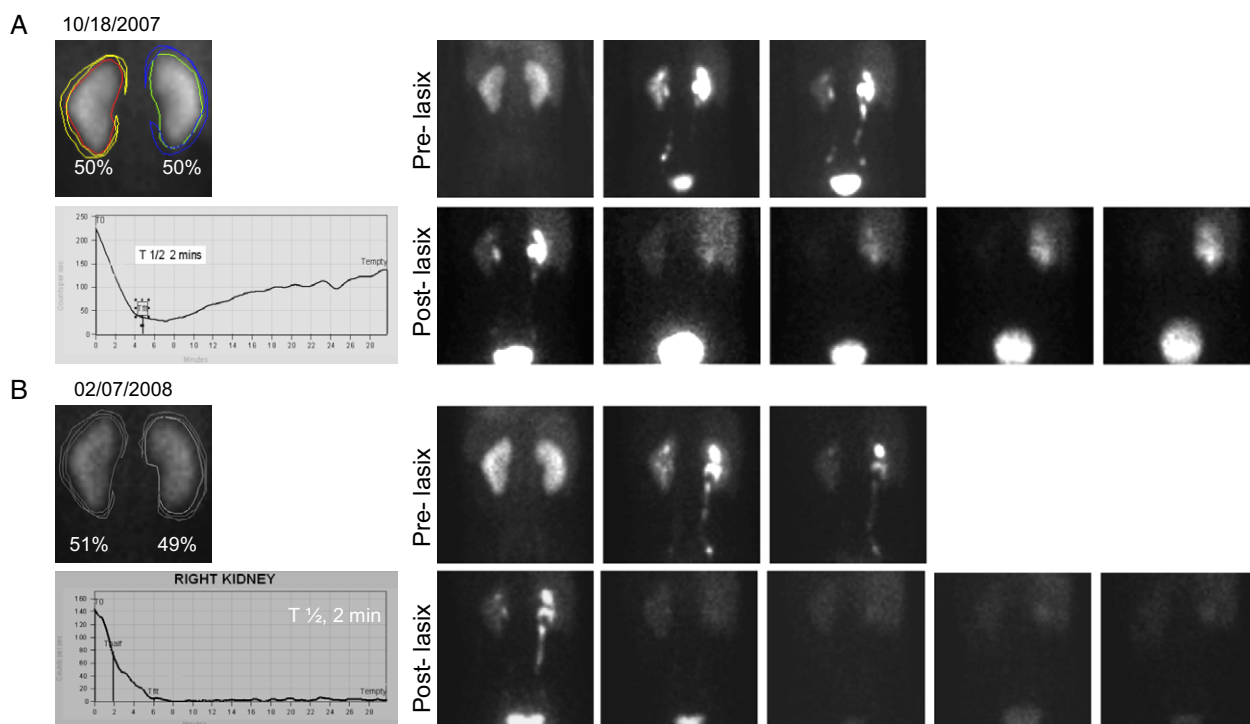


Figure 2. A, initial diuretic renogram reveals mild right hydronephrosis. After administration of furosemide there was rapid clearance of tracer from pelvicalyceal system with washout T_{1/2} of 2 minutes. Several minutes later right flank pain developed and there was gradual accumulation of tracer in right kidney (rising second part of curve). B, postoperative differential renal function remained stable and drainage improved significantly. *lasix*, furosemide.

pyeloplasty when DR demonstrated a T_{1/2} of 35 minutes and pain developed during the study (fig. 3), and 1 had presented with significant hydronephrosis and the initial DR revealed initially prompt drainage (T_{1/2} of 13 minutes). However, in the latter patient the drainage curve began to rise and flank pain developed. This patient underwent repeat DR, at which point the T_{1/2} increased to 26 minutes and once again the patient experienced pain. Overall the patients in group 3 showed stable to improved renal function and normal washout half-time following pyeloplasty.

Excluding the patients with CR, the remaining patients (46) were subdivided into groups based on DRF at presentation. Those with DRF less than 40% (mean 31.6%) demonstrated longer T_{1/2} (mean 76.8 minutes) than those with DRF 40% or greater (48.9%, 46.2 minutes, $p = 0.011$). Gravity assisted drainage was significantly less for patients with mean DRF less than 40% vs 40% or greater (13.2% vs 40.21%, $p = 0.0006$).

Diuretic renography precipitated flank/abdominal pain in 11 patients (1 from group 1, 8 from group 2 and 2 from group 3). Nine of these patients underwent only 1 study before pyeloplasty, while 2 underwent multiple studies before pyeloplasty. Three patients had biphasic drainage curves, of whom 1 had otherwise nonobstructive parameters.

DISCUSSION

Urinary tract obstruction has long been recognized as a cause of renal impairment. While patients with long-standing obstruction are more likely to exhibit renal function loss, patients with Dietl crisis rarely do so because obstruction is intermittent and relatively short lived. Most of our patients (71.7%) had preserved renal function (DRF 40% or greater) despite being an older group. Although we found statistically significant differences in renal differential function before and after pyeloplasty in patients with clearly obstructive DR (group 2), these differences were not clinically significant.

We have also observed that patients presenting with Dietl crisis have renographic findings, apart from half-time, that suggest obstruction, such as cortical clearance of the radiotracer, shape of the time-activity curve and diminished gravity assisted drainage. Indeed, the use of strict half-time cutoffs alone to define obstruction may be inconclusive.⁶

Cortical retention of the radiotracer is a sign of ongoing or recent acute obstruction, which is the equivalent of a delayed contrast nephrogram on CT. Acute ureteral obstruction causes decreased renal blood flow and reduced glomerular filtration rate.⁷ As a result, MAG3 is retained in the renal cortex with little or no transit into the dilated pelvicalyceal

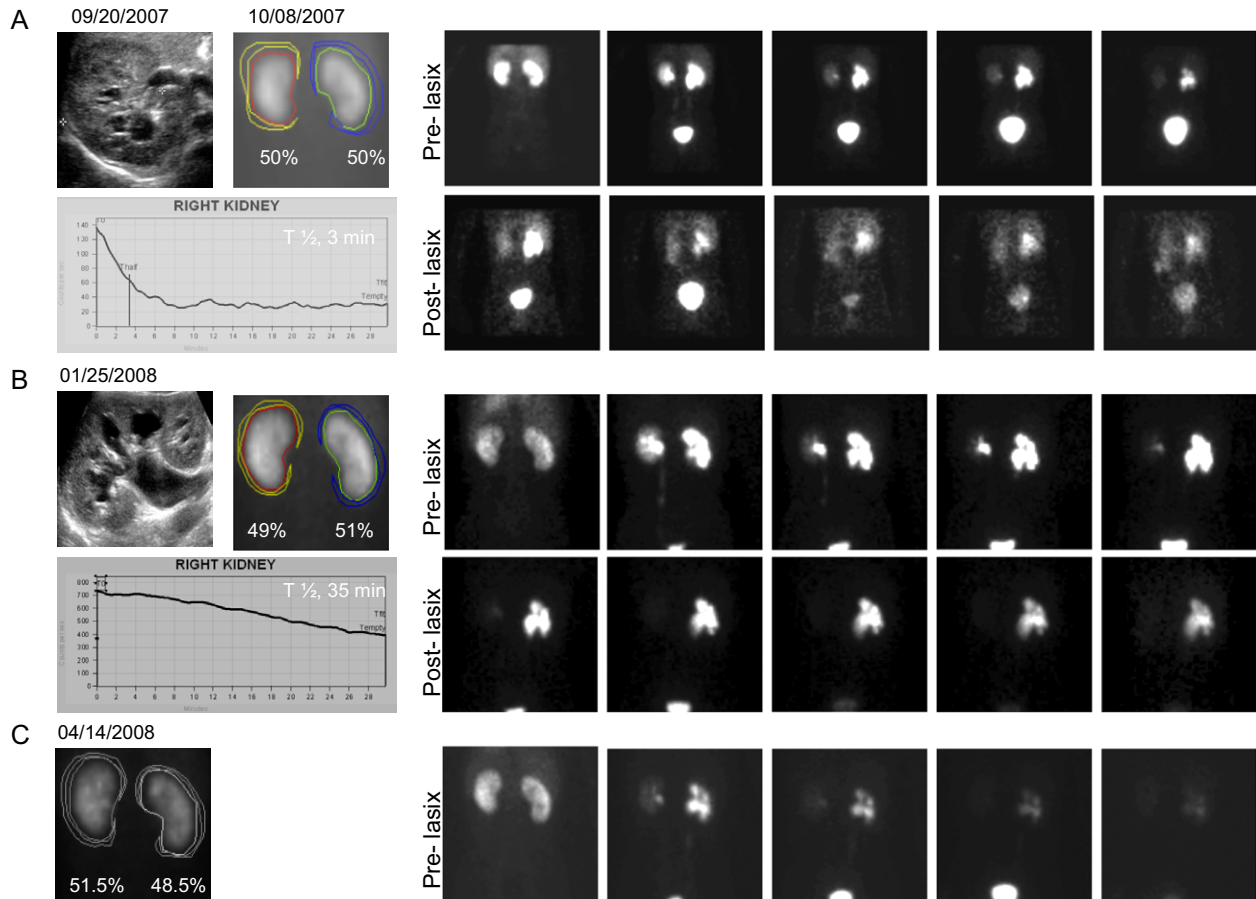


Figure 3. A, ultrasound shows mild right hydronephrosis in 7-year-old boy with right upper quadrant pain. Diuretic renogram demonstrates nonobstructive drainage. Patient presented second time with pain, and sonogram revealed increased dilatation of right collecting system. B, diuretic renogram shows worse drainage and patient reported pain after furosemide administration. C, following pyeloplasty, renography demonstrates prompt spontaneous drainage and, therefore, furosemide was not administered. *lasix*, furosemide.

system, which precludes accurate determination of differential renal function and obviates the use of furosemide to determine drainage half-times.

Renal function may be variably increased in select patients following resolution of acute obstruction. This series has revealed a trend toward increased differential renal function, which did not reach statistical significance perhaps because of limited sample size. Seven of 10 patients showed a mean improvement in differential renal function of 16.6% (range 9.5% to 31%) on followup imaging. In contrast, differential renal function after repair in the other patients remained essentially stable.

The shape of the drainage curve can be an important indicator of obstruction. While flat or rising curves represent high grade obstruction, prolonged drainage may also be suggested by decreased slope of the drainage curve quantified by the half-time. A more unusual shape is the biphasic drainage curve—one that is initially down sloping but then becomes either flat or uprising toward the end of the

curve. This finding represents a kidney that initially drains well but begins to exhibit signs of obstruction as the diuresis continues. These findings can vary from subtle to obvious and, when observed, suggest flow dependent obstruction.

The observation that a minority of patients demonstrates initially inconclusive DR is another indication of the intermittent nature of UPJ obstruction in some children. Of our patients 14% underwent repeat DR before obstruction was confirmed because of prolonged half-time or increased hydronephrosis (fig. 3).

Other factors, such as percent clearance of isotope after furosemide administration and gravity assisted drainage, are also important parameters and must be considered in analyzing the drainage curves. Obviously a lower percent of drainage at 30 minutes correlates with a higher degree of obstruction. This number typically correlates well with half-time. Gravity assisted upright drainage is an important parameter to consider, particularly when the

diagnosis is equivocal.⁸ Some kidneys that appear to be obstructed based on the initial 30 minutes of imaging in the supine position exhibit markedly improved clearance of retained radiotracer in the upright position. This finding suggests that drainage from the hydronephrotic pelvis may be position dependent. Conversely prolonged half-time associated with low percent clearance in the upright position suggests a more significant degree of obstruction.

In addition, it is important to pay attention to patient symptoms during diuretic renography. As observed in 11 of our patients, flank pain was precipitated by the administration of furosemide.

There are several limitations to this series. The retrospective nature of the study did not allow us to standardize or control the treatment and timing of treatments/studies across all patients. Also the dynamic nature of renal drainage can make it difficult to objectively compare preoperative and postoperative DR parameters. For example CR precludes the ability to calculate drainage because little or no radiotracer enters the collecting system. Conversely

postoperative drainage may improve so much that spontaneous drainage occurs even before furosemide can be administered. Finally, our cohort of patients is small, although this is the first known study to examine specific diuretic renography parameters in children with Dietl crisis.

CONCLUSIONS

The majority of patients with symptoms of intermittent renal obstruction have good preservation of renal function regardless of their renographic parameters at presentation. However, interpretation of MAG3 renal scan requires the assimilation of multiple parameters of the test, as patients with Dietl crisis can exhibit variability in renographic patterns due to the intermittent nature of the UPJ obstruction. Cortical retention represents a specific and pathognomonic finding of acute UPJ obstruction. With appropriate evaluation of these parameters, obstruction can be reliably diagnosed and appropriate surgical candidates chosen.

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