Procedure Guideline for Diuretic Renography in Children

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PART I: PURPOSE

The purpose of this guideline is to assist nuclear medicine practitioners in recommending, performing, interpreting and reporting the results of diuretic renography in children.

PART II: BACKGROUND INFORMATION AND DEFINITIONS

Hydronephrosis (distension of the pelvicalyceal system) is one of the most common indications for radionuclide evaluation of the kidneys in pediatric patients. The etiology of the hydronephrosis can be an obstructed renal pelvis, an obstructed ureter, vesicoureteral reflux, the bladder itself or the bladder outlet, infection or congenital in nature.

Contrast intravenous urography, ultrasonography and conventional radionuclide renography cannot reliably differentiate obstructive from nonobstructive causes of hydronephrosis and hydroureteronephrosis (distension of the pelvicalyceal system and ureter).

The pressure perfusion study (Whitaker test), which measures collecting system pressure under conditions of increased pelvic infusion is relatively invasive.

The evaluation of function in the presence of obstruction does not give reliable indication of potential for recovery following surgical correction. High pressure in the collecting system results in reduction of renal blood flow and function.

The most common cause of unilateral obstruction is the presence of a ureteropelvic obstruction. Obstructions can also occur more distally at the ureterovesical junction. Bilateral hydronephrosis can be produced by posterior urethral valves, bilateral ureteropelvic obstructions or even a full bladder.

The purpose of diuretic renography is to differentiate a true obstruction from a dilated nonobstructed system (stasis) by serial imaging after intravenous administration of furosemide (Lasix).

Hydronephrosis detected in utero may resolve spontaneously and is related to physiologic change during early development. The diagnosis of obstruction often requires sequential scintigraphic examinations.

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PART III: COMMON INDICATIONS

A. Ureteropelvic or ureterovesical obstruction
B. Prenatal ultrasound diagnosis of hydronephrosis
C. Postsurgical evaluation of a previously obstructed system
D. Distension of pelvicalyceal system as an etiology of back pain

PART IV: PROCEDURE

A. Patient Preparation
   1. Preparation prior to arrival in department
      Preparation is usually not necessary. If the patient is not going to receive intravenous fluids, oral hydration is encouraged prior to arrival and while in the department.
   2. Preparation prior to injection of the radiopharmaceutical
      a. The procedure is explained to parents and all children old enough to understand.
      b. Continual communication and reassurance with explanation of each step is essential for cooperation and successful intravenous injection of the radiopharmaceutical and catheterization of the bladder.
      c. In all patients being evaluated for obstruction, an indwelling venous catheter may be inserted to maintain sufficient hydration for a good diuretic effect and obviate the necessity for repeated traumas from multiple percutaneous injections.
      d. Bladder catheterization is suggested for all patients. Older children, who are not catheterized, are requested to void completely prior to the study.
         1. Sterile urethral catheterization should be performed with the largest size Foley or feeding catheter that will comfortably pass the meatus [a 2.6 mm diameter catheter (French #8) for most patients and 1.8 mm diameter (French #6) for infants]. A #8 French feeding catheter may also be used for continual bladder drainage.
         2. Continual drainage by catheterization of bladder is required in patients with hydroureter, vesicoureteral reflux, neurogenic bladder, a small capacity bladder, dysfunctional bladder or posterior urethral valves.
         3. The diuretic effect can be assessed by comparing the volume of urine excreted during the dynamic phase and the volume of urine excreted during the diuretic phase.

e. The patient is usually hydrated intravenously (10–15 ml/kg of D5 0.22% NS for under 1 yr and D5 0.45% NS for over 1 yr) for 30 min prior to administering the diuretic. The slow administration of fluid is continued during the remainder of the study.
f. If the rate of urine flow is low during hydration, a larger amount of fluid (up to 40 ml/kg) can be administered.
g. Some laboratories do not use intravenous hydration or catheter bladder drainage for the initial evaluation (particularly in older children) so that kidneys can be evaluated without intervention.

B. Information Pertinent to Performing the Procedure
1. A prenatal history of urinary tract obstruction, history of prior surgery to the urinary tract and congenital urinary abnormalities (duplex systems, renal fusion, etc.) are important for accurate interpretation of the study.
2. The review of available past radiographic, ultrasound and radionuclide studies adds to the accuracy of interpretation of the current study.
3. Nonlatex materials should be used in patients prone to latex allergy (e.g., congenital spinal defects and chronic urethral catheterization).
4. An allergy to sulfa drugs may prevent usage of furosemide (cross reactivity between sulfa and furosemide) in a small percentage of patients. Urethral anesthesia with xylocaine should not be used in patients with an allergic history.

C. Precautions
1. The examination table is covered with plastic-lined absorbent paper to contain spilled tracer and reduce contamination of the table during drainage and catheterization.
2. Gentle catheterization by a qualified individual can prevent an overly traumatic and painful experience and results in better cooperation during follow-up examinations.
3. Slow, deep breathing and a gentle forward motion of the catheter should be used to relax the spastic external sphincter.
4. An application of urethral anesthesia (3 to 5 ml of lidocaine jelly) in the male urethra 2–5 min before catheterization helps decrease the patient's discomfort.
5. A Foley balloon is only inflated after catheter and its balloon are confirmed to be in the bladder. Urine return can be appreciated with balloon still positioned in the posterior urethra. The balloon must be deflated prior to removal from the patient's bladder. When a feeding tube is used for bladder drainage, premeasurement of catheter length may prevent excessive instillation.
6. Caution should be observed with postural changes because of possible diuresis induced hypotension.
7. Sudden abdominal or flank pain can arise during acute distension of the pelvicalyceal system in some patients.
8. There is a small risk of catheter-induced trauma and infection (*1*).

D. Radiopharmaceutical (Table 1)
1. Technetium-99m-diethylene triamine pentaacetic acid (DTPA) is a glomerular agent. The biological half life is under 2.5 hr. Ninety-five percent of the administered dose is cleared by 24 hr.
2. Technetium-99m-mercaptoacetyltriglycine (MAG3) is cleared by tubular secretion. After about 3 hr, 90% of the injected dose can be recovered in the urine.
3. Technetium-99m-MAG3 has a high initial renal uptake, providing high kidney/background ratios with good temporal resolution. It is recommended for neonatal renography and for visualization of kidneys in patients with compromised renal function.
4. Iodine-131-orthoiodohippurate (OIH) (Hippuran) is cleared by tubular excretion (80%) and glomerular filtration (20%) with 90% clearance in the first pass through the kidney. The patient must be premedicated with several drops of potassium iodide oral solution (SSKI).
5. The minimal administered activity for ^{99m}Tc-DTPA is about 20 MBq (0.5 mCi). The maximum administered activity for ^{99m}Tc-DTPA is about 300 MBq (8.0 mCi).
6. The minimal administered activity for ^{99m}Tc-MAG3 is about 20 MBq (0.5 mCi). The maximum administered activity for ^{99m}Tc-MAG3 is about 300 MBq (8.0 mCi).
7. The minimal administered activity for ^{131}I-OIH is about 1.0 MBq (0.025 mCi). The maximum administered activity for ^{131}I-OIH is about 7 MBq (0.2 mCi).

Table 1
Radiation Dosimetry in Children*
(5-yr-old)

Radiopharmaceutical	Administered activity MBq/kg (mCi/kg)	Organ receiving the largest radiation dose† mGy (rad)	Effective dose† mSv (rem)
^{99m}Tc-DTPA	3.2–4.2 (0.08–0.12)	0.086 bladder wall (0.32)	0.012 (0.044)
^{99m}Tc-MAG3	3.2–4.2 (0.08–0.12)	0.17 bladder wall (0.63)	0.015 (0.056)
^{131}I-OIH	0.08–0.12 (0.002–0.004)	1.7 bladder wall (6.3)	0.12 (0.44)

* Treves ST. *Pediatric nuclear medicine*, 2nd ed. New York: Springer-Verlag; 1995:567–569.
† Per MBq (per mCi).

E. Image Acquisition
1. The preliminary study is a dynamic renal scan with the patient supine with his/her back to the camera and acquisition for 20–30 min as serial 15–30 sec images (64 × 64 or 128 × 128 matrix format). After the first few minutes, 30–60 sec images may be acquired.
2. For the diuretic phase, the supine position permits the least motion and is recommended for infants and most children. The sitting position is occasionally necessary but can result in motion, even in the most cooperative child.
3. The diuretic effect usually begins within 1–2 min after the administration of the diuretic.
4. Continuous computer and analog acquisitions are begun 1–2 min prior to the administration of the

diuretic (the baseline phase) and for the rest of the study.

5. The computer is set to record 15–60 sec frames for the baseline phase and for the additional 30 min with a 64 × 64 or 128 × 128 matrix format.

F. Interventions

1. The dose of furosemide (Lasix) is 1.0 mg/kg with a usual maximum dose of 40 mg. A higher diuretic dose may be necessary in cases of severe renal failure.
2. The diuretic is usually injected when the renal pelvis and ureter are maximally distended in hydronephrosis and hydroureter respectively. This may occur as early as 10–15 min but in most instances 30–40 min after the injection of the intravenous tracer.
3. Maximal distension is usually determined by visual inspection of the images.

G. Processing

1. From the dynamic renal study, careful evaluation of the parenchymal phase reveals renal function, size and position. Cortical transit time and dilatation of the collecting system are examined on the excretory phase.
2. Baseline images of the diuretic phase are used for the assessment of the diuretic effect.
3. Cinematic viewing of the diuretic phase assesses patient movement. If there is considerable patient motion, regions of interest around the collecting systems of individual frames will have to be compared at various time intervals of the study to assess drainage.
4. Regions of interest are drawn around the dilated pelvicalyceal system for curve analysis and calculation of the $T_{1/2}$. One to two background regions can also be drawn. The reader is referred to a standardized technique of the "well-tempered" diuretic renogram (*2*).
5. The diuretic half-time is the time at which the time-activity curve decreases to half of its maximal activity.
6. Residual activity can be reported by estimating the percentage of the initial tracer activity that remains at 30 min after the injection of the radiopharmaceutical.

H. Interpretation/Reporting

1. The diuretic effect usually begins within 1–2 min after the administration of the diuretic.
2. In absence of obstruction there is rapid and almost complete washout of the radiotracer.
3. Obstructed systems can result in delayed drainage from the collecting system. The amount of activity proximal to the obstruction can also increase in time.
4. A $T_{1/2}$ of less than 10 min usually means the absence of obstruction, whereas a $T_{1/2}$ of greater than 20 min identifies obstruction.
5. The $T_{1/2}$ with a value between 10 and 20 min is an equivocal result. However, some observers consider a $T_{1/2}$ of 10–15 min as probably normal.
6. The shape of resulting time activity curves of the washout study has been used for differentiation of stasis from obstruction.

I. Quality Control

There are no issues of quality control.

J. Sources of Error

1. Infiltration of the radiopharmaceutical or diuretic may invalidate the results.
2. Insufficient hydration can result in delayed uptake and excretion, simulating poor function or demonstrate a normal response in the presence of significant obstruction (*3*).
3. If the diuretic is administered prior to the maximum distension of the collecting system, the response may not reflect the true physiologic state.
4. Poor renal function from prolonged severe obstruction can result in slow tracer accumulation in the dilated collecting system and result in difficult interpretation of the diuretic phase.
5. With severe compromise of function (<20%), the diuretic response to furosemide (a tubular effect) may be difficult to evaluate when using ^{99m}Tc-DTPA, a glomerular agent (*4*).
6. A large, unobstructed collecting system with relatively good renal function can exhibit slow drainage of the radiotracer (prolonged $T_{1/2}$).
7. When the obstruction is at both pelvicalyceal and ureterovesical junctions, it may be difficult to detect the ureterovesical junction obstruction. A repeat evaluation may need to be performed following the surgical correction of the ureteropelvic junction obstruction.
8. Patient movement may invalidate curve analysis.
9. Urinary systems considered normal on the dynamic study should not be evaluated for drainage. A prolonged $T_{1/2}$ can be obtained because of the relatively small amount of residual activity in the collecting system to respond to the diuretic challenge.

PART V: DISCLAIMER

The Society of Nuclear Medicine has written and approved guidelines to promote the cost-effective use of high quality nuclear medicine procedures. These generic recommendations cannot be applied to all patients in all practice settings. The guidelines should not be deemed inclusive of all proper procedures or exclusive of other procedures reasonably directed to obtaining the same results. The spectrum of patients seen in a specialized practice setting may be quite different than the spectrum of patients seen in a more general practice setting. The appropriateness of a procedure will depend in part on the prevalence of disease in the patient population. In addition, the resources available to care for patients may vary greatly from one medical facility to another. For these reasons, guidelines cannot be rigidly applied.

Advances in medicine occur at a rapid rate. The date of a guideline should always be considered in determining its current applicability.

PART VI: ISSUES REQUIRING FURTHER CLARIFICATION

A. The calculation method of the diuretic half-time is variable but a standardized technique is available in the literature (*2*).

B. The curve analysis has been questioned because of poor correlation with pressure perfusion studies in children (*6,7*).

C. The results of alternative methods such as simultaneous injection of the radiopharmaceutical and diuretic or pre-injection of the diuretic remain to be validated.

D. Guidelines for doses of Lasix above usual maximums.

PART VII: CONCISE BIBLIOGRAPHY

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PART VIII: LAST HOUSE OF DELEGATES APPROVAL DATE

June 2, 1996

PART IX. NEXT ANTICIPATED APPROVAL DATE

1998

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Procedure Guideline for Radionuclide Cystography in Children

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Key Words: radionuclide cystography; practice guideline; vesicoureteral reflux; pediatric

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PART I: PURPOSE

The purpose of this guideline is to assist nuclear medicine practitioners in recommending, performing, interpreting and reporting the results of radionuclide cystography in children.

PART II: BACKGROUND INFORMATION AND DEFINITIONS

Urinary tract infection is a common problem in the pediatric population. The signs and symptoms are nonspecific, particularly in the younger child. The role of vesicoureteral reflux in the pathogenesis of pyelonephritis is incompletely understood. Approximately 50% of patients with upper urinary tract infection have vesicoureteral reflux. Urinary tract infection, unrecognized and inadequately treated, can lead to hypertension and chronic renal failure.

A. Radionuclide cystography is a method to evaluate for vesicoureteral reflux which results in significantly less gonadal radiation when compared to conventional radiographic technique (VCUG). In addition, radionuclide cystography has an equal sensitivity for detection of vesicoureteral reflux than the conventional radiographic technique. Radionuclide cystography does not provide the same anatomic detail as a VCUG.
B. Direct radionuclide cystography (DRC) requires catheterization of the bladder and instillation of radionuclide and fluid for maximum distension of the bladder, allowing imaging during filling, voiding and after voiding.
C. Indirect radionuclide cystography (IRC) does not require bladder catheterization but does require the intravenous injection of the radiopharmaceutical for evaluation of renal function, urine drainage, as well as detection of vesicoureteral reflux.

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