Society of Nuclear Medicine Procedure Guideline for Radionuclide Cystography in Children

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I. Purpose

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

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 40% 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. RNC is a method to evaluate for vesicoureteral reflux, which results in significantly less gonadal radiation when compared with conventional radiographic technique (VCUG). In addition, RNC has a sensitivity for detection of vesicoureteral reflux equal to that of VCUG. RNC does not provide the same anatomic detail as 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, and detection of vesicoureteral reflux.

III. Common Indications

A. Initial evaluation of females with urinary tract infection for reflux.
B. Diagnosis of familial reflux.
C. Evaluation of vesicoureteral reflux after medical management.
D. Assessment of the results of antireflux surgery.
E. Serial evaluation of bladder dysfunction (e.g., neurogenic bladder) for reflux.

IV. Procedure

A. Direct Radionuclide Cystography
   1. Patient preparation
      a. Preparation before arrival in the department
         There is usually no preparation necessary.
      b. Preparation before catheterization of the bladder
         i. The study is explained to parents and all children old enough to understand.
         ii. Continual communication and reassurance with explanation of each step is essential for success.
         iii. A calming effect can be produced by a quiet, dimly lit room, the watching of television, or even the reading of a story, making sedation rarely necessary.
         iv. The child may be instructed to void immediately before catheterization if residual volume (RV) is measured by catheterization rather than by computer analysis of bladder activity.
   2. Information pertinent to performing the procedure
      a. No latex materials should be used in pa-

tients prone to latex allergy (e.g., congenital spinal defects and chronic urethral catheterization). Urethral anesthesia with xylocaine should not be used in patients with an allergic history.

b. Histories of previous urinary tract infections, prior surgery to the urinary tract, antimicrobial prophylaxis, and congenital urinary abnormalities (duplex systems, etc.) are important.

c. Review of available past radiographic, ultrasound, and radionuclide studies adds to the accuracy of interpretation of the current study.

d. The bladder volume for the individual patient can be approximated in milliliters according to the formula:

(age in years + 2) χ 30 cc = bladder volume.

There is a nonlinear relationship between functional bladder capacity and patient's age.

Example for 6-mo-old: 0.5 y + 2 = 2.5 χ 30 = 75 cc.

e. The end of filling is usually achieved by the patient spontaneously voiding, by reaching the appropriate volume for the patient's age, or when there is cessation of flow from the bottle of solution (back-pressure effect) in a nonvoiding patient.

f. Cyclic voiding (multiple fills) results in greater detection of vesicoureteral reflux in infants and young children.

3. Precautions

a. The examination table is covered with plastic-lined absorbent paper to contain spilled radiopharmaceutical and reduce contamination of the table during DRC.

b. Gentle catheterization by a qualified individual can prevent an overly traumatic and painful experience and results in better cooperation during follow-up examinations.

c. Slow, deep breathing and a gentle forward motion of the catheter should be used to relax the spastic external sphincter.

d. An application of urethral anesthesia (3–5 mL lidocaine jelly) in the male urethra 2–5 min before catheterization helps decrease the patient's discomfort.

e. 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).

f. The Foley balloon is inflated only after the catheter and its balloon are confirmed to be in the bladder. For infants, inflating the balloon with 1 cc allows voiding around catheter without impairing bladder capacity.

i. Urine return can be appreciated even with the balloon still positioned in the posterior urethra.

ii. The balloon must be deflated for voiding portion of the study.

g. There is a small risk of catheter-induced infection.

4. Radiopharmaceutical

a. ^{99m}Tc-pertechnetate is usually used as the instillate.

b. ^{99m}Tc-sulfur colloid and ^{99m}Tc-diethylenetriaminepentaacetic acid (^{99m}Tc-DTPA) is nonabsorbable through bladder and bowel mucosa and should be used in the evaluation of augmented bladders.

c. The radiopharmaceutical can be mixed in a fixed volume of saline or irrigating solution (250–500 mL).

i. The container of solution is hung 100 cm above the table.

ii. The container of saline solution is surrounded by lead shielding and attached to the urethral catheter by venous tubing.

d. Another method introduces the radiopharmaceutical by injection directly into the catheter. Saline (10–20 cc) may be introduced first to reduce exposure to bladder mucosa.

i. The subsequent instillation of saline solution advances the radiopharmaceutical into the bladder.

ii. Increments of infusion can be recorded by the addition of a volume chamber to the intravenous setup.

iii. At times of reflux, approximate bladder volumes can be recorded.

5. Image acquisition

a. For the filling phase, the patient is supine with the head of the camera positioned posteriorly under the table. Cooperative children (older than 3 y) can sit on a table, the collimator being placed vertically against the back of the child.

b. The digital camera is equipped with a general-purpose collimator.

c. Computer images are obtained at a rate of 5 s per frame (128 χ 128 matrix suggested).

d. High-intensity analogue images may be

Radiation Dosimetry for Children[1] (5 years old)

Radiopharmaceutical	Administered Activity MBq (mCi)	Organ Receiving the Largest Radiation Dose[2, 3] Mgy/MBq (rad/Ci)	Effective Dose[3] MSv/MBq (rem/mCi)
^{99m}Tc-pertechnetate	18.5–37 (0.5–1.0)	0.028 bladder (0.10)	0.0024 (0.0089)
^{99m}Tc-sulfur colloid	18.5–37 (0.5–1.0)	0.028 bladder (0.10)	0.0024 (0.0089)
^{99m}Tc-DTPA	18.5–37 (0.5–1.0)	0.028 bladder (0.10)	0.0024 (0.0089)

[1]Treves ST. *Pediatric Nuclear Medicine.* 2nd ed. New York, NY: Springer-Verlag; 1995:569.
[2]Assumed activity in bladder for 15 min.
[3]Per MBq (per mCi).

taken every 30–60 s.

e. Voiding images are obtained with the camera positioned posteriorly, with the infant, toddler, or uncooperative child in the supine position and with the cooperative child sitting upright on a bedpan.
f. The computer images (128 χ 128 matrix suggested) of voiding are obtained every 2–10 s and analogue images may be taken every 30–60 s.
g. A 30-s anterior pre- and postvoid image can be obtained for calculation of residual bladder volume.

6. Interventions
   a. A urine specimen may be obtained for culture.
   b. Slowing the filling rate (particularly in infants) decreases bladder irritation and spasm and may permit satisfactory filling volumes.
   c. Maintenance of the catheter in place until the end of the study avoids additional catheterizations and permits recycling if the initial fill consists of an inappropriate volume to assess reflux.
7. Processing
   a. Routine evaluation of DRC is visual, utilizing contrast enhancement and dynamic imaging with cinematic display for detection of reflux.
   b. Quantitative techniques (activity per mL) are possible for evaluation of reflux, bladder volumes, and voiding flow rates but depend on avoidance of patient motion.
   c. Quantitation of postvoid RV requires regions of interest (ROIs) to be drawn over the bladder on pre- and postvoid images.
      i. The first method requires recording of volume of voided urine:

$$RV\ (mL) = \frac{\text{voided volume (mL)} \times \text{postvoid bladder counts (ROI)}}{\text{initial bladder counts (ROI)} - \text{postvoid bladder counts (ROI)}}$$

      ii. The second method requires an empty bladder for accurate calculation of RV:

$$RV\ (mL) = \frac{\text{postvoid bladder counts (ROI)} \times \text{volume infused}}{\text{initial bladder counts (ROI)}}$$

8. Interpretation criteria
   The radionuclide classification of reflux is less exacting and differs from the radiographic classification.
   a. RNC grade 1, with activity limited to the ureter. (Radiographic grade I)
   b. RNC Grade 2, with activity reaching the collecting system with none or minimal activity in ureter. (Radiographic grades II and III)
   c. RNC Grade 3, with a dilatation of the collecting system and dilated tortuous ureter. (Radiographic grades IV and V)
9. Reporting
   a. The basic information includes the procedure, the amount of the radiopharmaceutical and method of administration, the date, and whether it is a comparison study.

b. The history includes the symptoms and/or diagnosis.
c. The technique includes the size and type of catheter as well as the patient position during the study.
d. The findings include the number of bladder fills, the total volume instilled into bladder, the bladder volume at reflux, qualitative or quantitative assessment of magnitude of reflux duration during filling and voiding, and the qualitative or quantitative residual bladder volume.
e. The impression and recommendations may be included.

10. Quality control
See the Society of Nuclear Medicine *Procedure Guideline for General Imaging*.
11. Sources of error
a. A small-caliber catheter may not adequately drain the bladder if RV is to be measured by the catheterization technique. In some patients you must Credé the bladder.
b. Leakage and voiding can occur around the catheter in the young infant and toddler.
c. Mechanical factors, such as rapid filling of the bladder, temperature of solution, and irritation from the catheter, can cause increased tone of the bladder and premature micturition.
d. Urine contamination on the skin can sometimes be confused with vesicoureteral reflux.
e. RVs measured by catheterization and the radionuclide techniques may differ.

B. Indirect Radionuclide Cystography
1. Patient preparation
a. Preparation before arrival at the department
No preparation is required.
b. Preparation before injection of the radiopharmaceutical
i. The study is explained to parents and all children old enough to understand.
ii. Continual communication and reassurance with explanation of each step of the study is essential for success.
iii. Cooperation during the voiding phase is essential for performing IRC.

2. Information pertinent to performing the procedure
a. Histories of previous urinary tract infections, prior surgery to the urinary tract, antimicrobial prophylaxis, and congenital urinary abnormalities (duplex systems, etc.) are important.
b. Review of available past radiographic, ultrasound, and radionuclide studies adds to the accuracy of interpretation of the current study.
3. Precautions
Precautions to reduce contamination of room and equipment must be in place.
4. Radiopharmaceutical
a. ^{99m}Tc-mercaptoacetyltriglycine (^{99m}Tc-MAG3) is excreted principally through tubular secretion (preferred radiopharmaceutical because of less background activity).
i. The rapid clearance of this radiopharmaceutical results in less body background and less retention in the kidneys.
ii. This radiopharmaceutical is useful in older children with poorly function-

Radiation Dosimetry for Children (5 years old)

Radiopharmaceutical	Administered Activity MBq (mCi)	Organ Receiving the Largest Radiation Dose[1] MGy per MBq (rad per mCi)	Effective Dose[1] MSv per MBq (rem per mCi)
^{99m}Tc-MAG3	3.2 – 4.2 (0.08 – 0.12)	0.17 bladder (0.63)	0.015 (0.056)
^{99m}Tc-DTPA	3.2 – 4.2 (0.08 – 0.12)	0.086 bladder (0.32)	0.012 (0.044)

[1]Per MBq (per mCi)

ing kidneys.

iii. 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).

b. ^{99m}Tc-diethylenetriaminepentaacetic acid (^{99m}Tc-DTPA) is excreted primarily by glomerular filtration.

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).

5. Image acquisition
   a. IRC requires a conventional dynamic renal scan before the voiding phase of the study (see image acquisition, section F, SNM *Procedure Guideline for Diuretic Renography in Children*).
   b. The patient lies supine with the gamma camera positioned posteriorly beneath the imaging table.
   c. Analogue images may be obtained at 1–4-s intervals for the first min, followed by timed images at 1–5-min intervals for 30–60 min.
   d. Computer acquisition may be at a rate of 10–20 s per frame for determination of differential renal function. Blood flow phase may require 0.5 s/frame for 40–60 s.
   e. Drainage of activity from the kidneys before the recording of the voiding phase can be assisted by the erect position.
   f. If activity persists in the kidneys and ureters, the child can wait until it clears (if the child can hold his/her urine) or wait for bladder to refill after voiding.
   g. The child is positioned in the sitting position with the gamma camera centered posteriorly over the region of the bladder and kidneys.
   h. Recording of 2–5-s computer images is initiated when the child has the urge to void and continues until the end of voiding.
   i. Emptying of the bladder takes place into a urinal, bedpan, or specially constructed commode.
   j. Lack of patient motion is important during image acquisition.
6. Interventions
   None
7. Processing
   a. Cinematic display with contrast enhancement assists in the detection of vesicoureteral reflux.
   b. Curve analysis may demonstrate a sudden increase in activity in the collecting system and ureter indicative of vesicoureteral reflux.
   c. The voided volume of urine can be measured (volume or weight), and the count difference between pre- and postvoid bladder curves may be converted to milliliters, thus allowing estimation of bladder activity as well as estimating the volume of the renal pelvis.
8. Interpretation criteria
   a. Mild-to-moderate grades of reflux are difficult to detect.
   b. This study probably should be reserved for instances when catheterization is impossible.
9. Reporting
   a. The basic information includes the procedure, the amount of the radiopharmaceutical and method of administration, the date, and whether it is a comparison study.
   b. The history includes the symptoms and/or diagnosis.
   c. The technique includes imaging sequence and patient positioning for pre- and postvoid imaging.
   d. The findings include renal perfusion, differential renal function, progression of activity, and presence of reflux during voiding.
10. Quality control
    None
11. Sources of error
    There is a high failure rate because of the inability of children to void at the proper time or at all. There is a false-negative rate of determination reflux when using the indirect procedure. Most reflux that is overlooked is minor (grade I) and may be of no clinical significance.

V. Issues Requiring Further Clarification

There are no issues identified.

VI. Concise Bibliography

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VII. 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 from 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.