and nephrology. East Norwalk, CT: Appleton, Century and Crofts; 1985:305–320.
2. Conway JJ. "Well-tempered" diuresis renography: its historical, development, physiological and technical pitfalls, and standardized technique protocol. *Semin Nucl Med* 1992;22:74–84.
3. Wackman J, Brewer E, Gelfand MJ, et al. Low grade pelviureteric obstruction with normal diuretic renography. *Br J Urol* 1986;58:364–367.
4. Kass EJ, Majd M. Evaluation and management of the upper urinary tract obstruction in infancy and childhood. *Urol Clin NA* 1985;12:122–141.
5. Meller ST, Eckstein HB. Renal scintigraphy: quantitative assessment of upper urinary tract dilatation in children. *J Pediatr Surg* 1981;16:123–126.
6. Senac MO, Miller JH, Stanley P. Evaluation of obstructive uropathy in children: radionuclide renography versus the Whitaker test. *AJR* 1984;143:11–15.
7. Whitaker RH, Buxton TMS. A comparison of pressure flow studies and renography in equivocal upper tract obstruction. *J Urol* 1986;131:446–449.

PART VIII: LAST HOUSE OF DELEGATES APPROVAL DATE

June 2, 1996

PART IX. NEXT ANTICIPATED APPROVAL DATE

1998

ACKNOWLEDGMENTS

Henry D. Royal, MD, chair of the Guidelines and Communications Committee, Commission on Health Care Policy and Practice, for overall coordination and oversight of the SNM Guideline Development Project; Wendy Smith, MPH, Director of Health Care Policy, Society of Nuclear Medicine, for project coordination, data collection and editing; members of the Pediatric Imaging Council and members of the Guideline Development Subcommittee who contributed their time and expertise to the development of this information.

Procedure Guideline for Radionuclide Cystography in Children

Gerald A. Mandell, Douglas F. Eggli, David L. Gilday, Sydney Heyman, Joe C. Leonard, John H. Miller, Helen R. Nadel and S. Ted Treves

A.I. Dupont Institute, Wilmington, Delaware; Pennsylvania State University/Milton S. Hershey Medical Center, Hershey, Pennsylvania; Hospital for Sick Children, Toronto, Ontario, Canada; Children's Hospital of Philadelphia, Philadelphia, Pennsylvania; Oklahoma Children's Memorial Hospital, Oklahoma City, Oklahoma; Children's Hospital Los Angeles, Los Angeles, California; Children's Hospital, British Columbia, Vancouver, Canada; and Children's Hospital, Boston, Massachusetts

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

J Nucl Med 1997; 38;1650–1654

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.

Received Jun. 17, 1997; accepted Jun. 17, 1997.

For correspondence or reprints contact: Wendy J.M. Smith, Associate Director of Health Care Policy, 1850 Samuel Morse Dr., Reston, VA 20190-5316 or via e-mail at wsmith@snm.org.

Note: All 26 SNM-approved procedure guidelines are available on the Society's home page. We encourage you to download these documents via the Internet at http: \\www.snm.org. If you would like information on the development process of this guideline or to order a compendium of all 26 procedure guidelines for $20.00, please contact Wendy J.M. Smith, Society of Nuclear Medicine at (703) 708-9000, ext. 242 or via e-mail at wsmith@snm.org.

PART III: COMMON INDICATIONS

A. Initial evaluation of females with urinary tract infection for reflux
B. Diagnosis of familial reflux
C. Follow-up of vesicoureteral reflux following a course of antibiotic therapy
D. Assessment of the results of anti-reflux surgery
E. Serial evaluation of bladder dysfunction (e.g., neurogenic bladder) for reflux

PART IV: PROCEDURE

A. Direct Radionuclide Cystography
1. Patient Preparation
a. Preparation prior to arrival in the department
There is usually no preparation necessary.
b. Preparation prior to catheterization of the bladder
1. The study is explained to parents and all children old enough to understand.
2. Continual communication and reassurance with explanation of each step is essential for success.
3. A calming effect can be produced by a quiet, dimly lit room, watching television or even reading a story, making sedation rarely necessary.
4. The child may be instructed to void immediately prior to catheterization, if residual volume is measured by catheterization rather than by computer analysis of bladder activity.
2. Information Pertinent to Performing the Procedure
a. Nonlatex materials should be used in patients 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. History 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) × 30 cc (*1*). There is a nonlinear relationship between functional bladder capacity and patient's age (*2*).
e. The end of filling is usually determined by reaching appropriate volume for patient's age and/or cessation of flow from the bottle of solution (back pressure effect).
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 of 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 only inflated after 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.
1. Urine return can be appreciated even with the balloon still positioned in the posterior urethra.
2. The balloon must be deflated for voiding portion of the study.
g. There is a small risk of catheter-induced infection (*3*).
4. Radiopharmaceutical (Table 1)
a. Technetium-99m-pertechnetate is usually used as the instillate (*4*).
b. Technetium-99m sulfur colloid and ^{99m}Tc-diethylene triamine pentaacetic acid (DTPA) are non-absorbable 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).
1. The container of solution is hung 70–100 cm above the table.
2. 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; 10–20 cc of saline may be introduced first to reduce exposure to bladder mucosa.
1. The subsequent instillation of saline solution advances the radiopharmaceutical into the bladder.

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-pertechnetate	18.5–37	0.028 bladder	0.0024
	(0.5–1.0)	(0.104)	(0.0088)
^{99m}Tc-sulfur colloid	18.5–37	0.028 bladder	0.0024
	(0.5–1.0)	(0.104)	(0.0088)
^{99m}Tc-DTPA	18.5–37	0.028 bladder	0.0024
	(0.5–1.0)	(0.104)	(0.0088)

*Assumed activity in bladder for 15 min.
†Treves ST. *Pediatric nuclear medicine*, 2nd ed. New York: Springer-Verlag; 1995:569.
‡Per MBq (per mCi).

2. Increments of infusion can be recorded by the addition of a volume chamber to the intravenous setup.
3. 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.
   b. The digital camera is equipped with a general purpose collimator.
   c. Computer images are obtained at a rate of 5 sec per frame (128 × 128 matrix).
   d. High-intensity analogue images are taken every 30–60 sec.
   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 bed pan.
   f. The computer images (128 × 128 matrix) of voiding are obtained every 2–10 sec, and analogue images may be taken every 30–60 sec.
   g. A 30-sec anterior pre-void and post-void 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. Maintaining the catheter in place until the end of the study avoids additional catheterizations if the initial fill consists of an inappropriate volume to assess reflux.
   d. Saline at body temperature if multicyclic technique is desired.
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 (*5*).
   c. Quantitation of post-void residual volume (RV) requires recording of volume of voided urine.
      1. Regions of interest (ROI) are drawn over bladder on both anterior and posterior pre-void images.
      2.

$$\text{RV (ml)} = \frac{\text{voided vol (ml)} \times \text{post-void bladder counts (ROI)}}{\text{initial bladder counts (ROI)} - \text{post-void bladder counts (ROI)}}$$

3.

$$\text{RV (ml)} = \frac{\text{post-void bladder counts (ROI)}}{\text{initial bladder counts (ROI)}} \times \text{volume infused}$$

8. Interpretation/Reporting
   a. The presence and duration of reflux during each phase of the study is reported.
   b. The post-void residual volume is recorded if patient's bladder emptied completely before the start of the study.
   c. Radionuclide classification of reflux differs from the radiographic classification.
      1. Mild reflux corresponds to tracer just in the ureter.
      2. Moderate reflux is the accumulation of activity in a non-dilated collecting system and ureter.
      3. Severe reflux is equated with a dilated ureter and collecting system.
9. Quality Control
   See the *Society of Nuclear Medicine Procedure Guideline for General Imaging.*
10. Sources of Error
   a. A small caliber catheter may not adequately drain the bladder if residual volume is to be measured by the catheterization technique. In some patients you must crede 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 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. Residual volumes measured by catheterization and the radionuclide techniques may differ.

B. Indirect Radionuclide Cystography
1. Patient Preparation
   a. Preparation prior to arrival at the department
   No preparation is required.
   b. Preparation prior to the injection of the radiopharmaceutical
      1. The study is explained to parents and all children old enough to understand.
      2. Continual communication and reassurance with explanation of each step of the study is essential for success.
      3. Cooperation during the voiding phase is essential for performing IRC.
2. Information Pertinent to Performing the Procedure
   a. History 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 (Table 2)
   a. Technetium-99m-mercaptoacetyltriglycine (MAG3) is excreted principally through tubular secretion.
      1. The rapid clearance of this radiopharmaceutical results in less body background and less retention in the kidneys.
      2. This radiopharmaceutical is useful in older children with poorly functioning kidneys.
      3. The minimal administered activity for ^{99m}Tc-MAG3 is about 20 MBq (0.5 mCi). The

TABLE 2
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-MAG3	3.2–4.2	0.17 bladder	0.015
	(0.08–0.12)	(0.63)	(0.056)
^{99m}Tc-DTPA	3.2–4.2	0.086 bladder	0.012
	(0.08–0.12)	(0.32)	(0.044)

*Per MBq (per mCi).

maximum administered activity for ^{99m}Tc-MAG3 is about 300 MBq (8.0 mCi).

b. Technetium-99m-diethylene triamine pentaacetic acid (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 prior to the voiding phase of the study.
   b. The patient lies supine with the gamma camera positioned posteriorly beneath the imaging table.
   c. Analogue images may be obtained at 1–4 sec intervals for the first minute, followed by timed images for 1–5 min intervals for 30–60 min.
   d. Computer acquisition may be at a rate of one frame per second for 1–2 min for the early parenchymal phase and at 15-sec to 1-min intervals for the parenchymal and washout phases of the study.
   e. Drainage of activity from the kidneys prior to 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 gamma camera centered posteriorly over the region of the bladder and kidneys.
   h. Recording of 2–10 sec 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 or a bed pan 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.
8. Interpreting/Reporting
   a. The presence of reflux can be detected only during voiding and not during filling.
   b. Mild to moderate grades of reflux are difficult to detect (*6*). This study probably should be reserved for instances when catheterization is impossible.
9. Quality Control
   There are no issues of quality control.
10. Sources of Error
    There is a high failure rate because of inability of a child to void at the proper time or at all.

    There is a 41% false-negative rate of determination reflux when using the indirect procedure.

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

None

PART VII: CONCISE BIBLIOGRAPHY

1. Berger RM, Maizels M, Moren OC, et al. Bladder capacity (ounces) equals age (years) plus 2 predicts the normal bladder capacity and aids in diagnosis of abnormal voiding patterns. *J Urol* 1983;129:347–349.
2. Treves ST, Zurakowski D, Bauer SB, et al. Functional bladder capacity measured during radionuclide cystography. *Radiology* 1996;198:269–272.
3. Conway JJ, King LR, Belman AB, et al. Detection of vesicoureteral reflux with radionuclide cystography. *Am J Roentgenol Radium Ther Nucl Med* 1972;115:720–727.
4. Conway JJ. Radionuclide cystography. In: Tauxe WN, Dubovsky EV, eds. *Nuclear medicine in clinical urology and nephrology*. East Norwalk, CT: Appleton; 1985: 305–320.
5. Treves ST, Gelfand M, Willi UV. Vesicoureteric reflux and radionuclide cystography. In: Treves ST, ed. *Pediatric nuclear medicine, 2nd ed.* New York: Springer-Verlag; 1995:411–429.
6. Willi U, Treves S. Radionuclide voiding cystography. *Urol Radiology* 1983;5:161–173.

PART VIII: LAST HOUSE OF DELEGATES APPROVAL DATE

June 2, 1996

PART IX: NEXT ANTICIPATED APPROVAL DATE

1998

ACKNOWLEDGMENTS

Henry D. Royal, MD, chair of the Guidelines and Communications Committee, Commission on Health Care Policy and Practice, for overall coordination and oversight of the SNM Guideline Development Project; Wendy Smith, MPH, Director of Health Care Policy, Society of Nuclear Medicine, for project coordination, data collection and editing; members of the Pediatric Imaging Council and members of the Guideline Development Subcommittee who contributed their time and expertise to the development of this information.

Procedure Guideline for Hepatobiliary Scintigraphy

Helena R. Balon, Darlene M. Fink-Bennett, David R. Brill, Lorraine M. Fig, John E. Freitas, Gerbail T. Krishnamurthy, William C. Klingensmith III and Henry D. Royal

William Beaumont Hospital, Royal Oak, Michigan; Geisinger Medical Center, Danville, Pennsylvania; VA Medical Center, Ann Arbor, Michigan; St. Joseph Mercy Hospital, Ann Arbor, Michigan; VA Medical Center, Tucson, Arizona; Porter Hospital, Denver, Colorado; and Mallinckrodt Institute of Radiology, St. Louis, Missouri

Key Words: liver function; cholecystitis; gallbladder; radionuclide imaging; practice guideline

J Nucl Med 1997; 38:1654–1657

PART I: PURPOSE

The purpose of this procedure guideline is to assist nuclear medicine practitioners in recommending, performing, interpreting and reporting the results of hepatobiliary scintigraphy.

PART II: BACKGROUND INFORMATION AND DEFINITIONS

Hepatobiliary scintigraphy is a diagnostic imaging study that evaluates hepatocellular function and patency of the biliary system by tracing the production and flow of bile from the liver through the biliary system into the small intestine. Sequential images of the liver, biliary tree and gut are obtained. Computer acquisition and analysis as well as pharmacological interventions are frequently used.

PART III: COMMON INDICATIONS

A. Functional assessment of the hepatobiliary system
B. Integrity of the hepatobiliary tree

These broad categories include, for example:

- Evaluation of suspected acute cholecystitis.
- Evaluation of suspected chronic biliary tract disorders.
- Evaluation of common bile duct obstruction.
- Detection of bile leak.
- Evaluation of congenital abnormalities of the biliary tree (e.g., biliary atresia)

PART IV: PROCEDURE

A. Patient Preparation

To permit gallbladder (GB) visualization, the patient must have fasted for a minimum of two and preferably four hours prior to administration of the radiopharmaceutical. If the patient has fasted for 24 hr or longer or is on parenteral nutrition, a false-positive study may occur (*1*). In these cases (especially with total parenteral nutrition (TPN), the patient may be pretreated with sincalide, see IV.F.1. below (*2*).

Received Dec. 18, 1996; accepted Jun. 17, 1997.

For correspondence or reprints contact: Wendy J.M. Smith, Director of Health Care Policy, 1850 Samuel Morse Dr., Reston, VA 20190-5316 or via e-mail at wsmith@snm.org.

Note: All 26 SNM-approved procedure guidelines are available on the Society's home page. We encourage you to download these documents via the Internet at http: \\www.snm.org. If you would like information on the development process of this guideline or to order a compendium of all 26 procedure guidelines for $20.00, please contact Wendy J.M. Smith, Society of Nuclear Medicine at (703) 708-9000, ext. 242 or via e-mail at wsmith@snm.org.

TABLE 1
Radiation Dosimetry for Adults

Radiopharmaceuticals	Administered activity MBq (mCi)	Organ receiving the largest radiation dose*† mGy (rad)	Effective dose*† mSv (rem)
^{99m}Tc-disofenin	50–200 i.v.	0.11	0.024
^{99m}Tc-mebrofenin	(1.5–5.0)	Gallbladder wall (0.41)	(0.089)

*ICRP 53, page 203, normal liver function.
†Per MBq (per mCi).

B. Information Pertinent to Performing the Procedure

The physician should review all available pertinent clinical, laboratory, radiographic and sonographic information about the patient prior to the study. Additional information specifically related to hepatobiliary scintigraphy includes:

1. History of previous surgeries, especially biliary and gastrointestinal.
2. Time of most recent meal.
3. Current medications, including the time of their most recent administration (with particular attention to opioid compounds).
4. Results of bilirubin and liver enzyme levels.
5. Results of ultrasound.

C. Precautions

The test should be performed under the optimal state of fasting to avoid a false-positive result. Interference by opioids can be minimized by delaying the study for 4 hr after the last dose. Additional details are listed in IV.A. ("Patient Preparation") and IV.I. ("Sources of Error").

D. Radiopharmaceutical

Technetium-99m-labeled disofenin (DISIDA, 2,6-diisopropylacetanilido iminodiacetic acid) or mebrofenin (BRIDA, bromo-2,4,6-trimethylacetanildo iminodiacetic acid) is administered intravenously in activities of 50-200 MBq (1.5–5.0 mCi) for adults (Table 1); higher dosages will be needed in hyperbilirubinemia, 100–370 MBq (3–10 mCi) (*3*). Mebrofenin may be selected instead of disofenin in moderate-to-severe hyperbilirubinemia due to its somewhat higher hepatic extraction. For infants and children, the administered activity is 2–7 MBq/kg (0.05–0.2 mCi/kg) with a minimum of 15–20 MBq (0.4–0.5 mCi) (Table 2).