Revised 2008 (Resolution 12)*

ACR–SPR PRACTICE GUIDELINE FOR THE PERFORMANCE OF ADULT AND PEDIATRIC RENAL SCINTIGRAPHY

PREAMBLE

These guidelines are an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the American College of Radiology cautions against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the physician or medical physicist in light of all the circumstances presented. Thus, an approach that differs from the guidelines, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of the guidelines. However, a practitioner who employs an approach substantially different from these guidelines is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to these guidelines will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these guidelines is to assist practitioners in achieving this objective.

I. INTRODUCTION

This guideline was revised collaboratively by the American College of Radiology (ACR) and the Society for Pediatric Radiology (SPR) to guide interpreting physicians performing renal scintigraphy in adult and pediatric patients. Renal scintigraphy involves the intravenous injection of a radiopharmaceutical, which is extracted from the bloodstream by the kidneys, and subsequent imaging on a gamma camera, with computer acquisition. Quantitative functional studies using a well counter to assay blood and/or urine samples may be obtained in conjunction with, or in lieu of, renal scintigraphy.

Properly performed, renal scintigraphy is a sensitive means for detecting, evaluating, and quantifying numerous renal disorders. Pharmacologic manipulation may enhance the sensitivity of detecting and evaluating certain disease states. It also is possible to accurately quantify some parameters of renal function. As with all scintigraphic studies, correlation of findings with the results of other imaging and nonimaging procedures, as well as with clinical information, is imperative for maximum diagnostic yield.

Application of this standard should be in accordance with the ACR–SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals.

II. GOAL

The goal of renal scintigraphy is to enable the physician to detect anatomic or functional abnormalities of the kidneys or urinary tract by interpreting images and/or digital data of diagnostic quality.

III. INDICATIONS

Clinical indications for renal scintigraphy include, but are not limited, to detection, evaluation, and/or quantification of:

1. Renal function
2. Congenital and acquired anatomic renal abnormalities
3. Urinary tract obstruction
4. Renovascular disease
5. Pyelonephritis and parenchymal scarring
6. Functional and anatomic abnormalities of transplanted kidneys
7. Parameters of renal function, including effective renal plasma flow (ERPF), glomerular filtration rate (GFR), and differential renal function.

For the pregnant or potentially pregnant patient, see the ACR Practice Guideline for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation.

IV. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR–SNM Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals.

V. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for renal scintigraphy should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state scope of practice requirements. (ACR Resolution 35, adopted in 2006)

A. Radiopharmaceuticals

Radiopharmaceuticals for evaluation of the kidneys may be classified into 3 broad categories.

1. Glomerular agents: mainly excreted by glomerular filtration.

   a. Technetium-99m diethylenetriamine penta-acetic acid (DTPA)
      This agent is excreted predominantly by glomerular filtration and can be used to measure GFR. Excretion by the kidneys is significantly affected by reduced renal function. The agent may be used to assess renal blood flow and function, renal transplants, suspected renovascular hypertension, and obstructive uropathy. For dynamic renal scintigraphy, administered activity of up to 15 millicuries (555 MBq) may be given to adults. For children, administered activities are typically in the range of 100 to 200 microcuries (3.7 to 7.4 MBq) per kilogram, with a minimum of 1.0 millicurie (37 MBq) and a maximum of 10.0 millicuries (370 MBq). If the study is performed for calculation of GFR without imaging, the administered activity may be reduced to 200 to 500 microcuries (7.4 to 18.5 MBq).

   b. Iodine-125 iothalamate (Glofil™)
      This agent is used in dosages of 10 to 50 microcuries (0.37 to 1.85 MBq) for the nonimaging assessment of GFR.

2. Cortical agents: primarily taken up by tubular cells.

   a. Technetium-99m dimercaptosuccinic acid (DMSA)
      This agent is taken up by renal tubular cells with a component of glomerular filtration. It is an excellent parenchymal imaging agent. Technetium-99m DMSA may be used to assess the size, shape, position, and relative functional cortical mass of the kidneys. It may also be used in detecting pyelonephritis and renal cortical scars. Administered activity of up to 5.0 millicuries (185 MBq) may be given to adults. For children, an administered activity of 0.05 to 0.1

millicurie (1.85 to 3.7 MBq) per kilogram is usually given, with a minimum of 0.3 to 1.0 millicurie (11.1 to 37 MBq) and a maximum of 3.0 to 5.0 millicuries (111 to 185 MBq)[1].

b. Technetium-99m glucoheptonate (GHA)
This agent is partly bound by tubules and partly excreted by glomerular filtration. Its ability to localize in the kidney is moderately impaired by reduced renal function. Technetium-99m GHA may be used qualitatively for evaluating the size, shape, and position of focal parenchymal scars and pyelonephritis and the relative functional cortical mass of kidneys. Administered activity of up to 15 millicuries (555 MBq) may be used in adults. Pediatric administered activities are usually 100 to 150 microcuries (3.7 to 5.55 MBq) per kilogram, with a minimum of 1.0 millicurie (37 MBq).

3. Tubular agents: mainly excreted by tubular secretion.

Technetium-99m mercaptoacetyl triglycine (MAG3)
This agent is rapidly extracted and secreted by tubular cells in a manner that is qualitatively similar to the action of orthoiodohippurate (OIH). Renal uptake is reduced by poor function but not as severely as with technetium-99m DTPA or technetium-99m GHA. The agent may be used quantitatively or qualitatively for evaluating obstructive uropathy, renovascular hypertension, and renal transplant abnormalities and has been used to approximate ERPF measurement. Administered activity of up to 10 millicuries (370 MBq) is used for adults. Pediatric administered activity ranges from 50 to 100 microcuries (1.85 to 3.7 MBq) per kilogram, with a minimum of 0.5 to 1.0 millicurie (18.5 to 37 MBq) and a maximum of 5.0 millicuries (185 MBq).

B. Radionuclide Renography

Radionuclide renography refers to serial imaging after intravenous administration of DTPA or MAG3. It is used for qualitative evaluation of overall renal function and calculation of differential renal function. A commonly used technique involves dynamic acquisition of 1-second images for 1 minute (blood flow phase), followed by acquisition of 15-second images for at least 20 minutes (functional and drainage phases). If evaluation of renal blood flow is not needed, the study is performed without the first phase. A region of interest is drawn around each kidney. A background region of interest is also drawn and a background subtracted time-activity curve is generated. The renal differential function is calculated based on the relative counts accumulated in each kidney during the second minute after injection of the radiopharmaceutical.

C. Diuretic Renography

Diuretic renography is used to differentiate a dilated but nonobstructed collecting system from a dilated system with urodynamically significant obstruction. It is also useful for assessing functional and urodynamic results of corrective surgery.

A commonly used technique includes intravenous administration of technetium-99m MAG3 or technetium-99 DTPA and acquisition of dynamic 15-second posterior renal images for 20 to 30 minutes. Furosemide, 0.5 mg/kg (1 mg/kg for children) with a maximum dose of 40 mg, is then administered intravenously, and dynamic 15-second renal images are obtained for another 20 to 30 minutes. The initial set of images is used for evaluating overall and split renal function. The images obtained after administration of furosemide are used for quantitative analysis of postdiuresis clearance of the tracer from the dilated collecting systems. Regions of interest, including the entire dilated collecting system, are drawn and a background subtracted time-activity curve is generated. A less commonly used technique is simultaneous administration of radiopharmaceutical and furosemide followed by dynamic acquisition of renal images for 30 minutes.

Diuretic renography is usually performed with the patient in the supine position. This may cause delayed clearance of the tracer from some dilated but nonobstructed collecting systems. Therefore, an additional static image after the patient has been in an upright position for 10 to 15 minutes will help to assess gravity-assisted clearance and improve the accuracy of the test.

It is important to assure that the patient is well hydrated. Intravenous fluid infusion is particularly useful in children. A distended bladder may prolong renal collecting system drainage. Depending on clinical circumstances, an indwelling bladder catheter may be necessary to assess adequately for obstruction of the upper tracts.

The natural history of hydronephrosis in children, particularly in neonates, is variable, and definitive diagnosis of obstructive uropathy on a single diuretic renogram is often difficult. Multiple exams at appropriate intervals may be needed to detect gradual improvement or worsening of the postdiuresis drainage. Therefore,

[1]For more specific guidance on pediatric dosing, please refer to the *Pediatric Radiopharmaceutical Administered Doses: 2010 North American Consensus Guidelines* [9]

whatever technique is used, it should be standardized in order to allow meaningful comparison of the studies in each patient.

D. Captopril (ACE inhibitor) Renography

Renovascular hypertension is caused by hemodynamically significant stenosis of the renal artery or one of its branches. However, renal artery stenosis may be an associated but nonetiologic finding in some hypertensive patients. Therefore, the goals of renal scintigraphy in the evaluation of hypertensive patients are: a) to identify those who have renal artery stenosis as the cause of their hypertension and would benefit from revascularization, and b) to identify those who do not have renovascular hypertension and avoid unnecessary renal angiography or revascularization.

In the presence of hemodynamically significant renal artery stenosis, renal perfusion pressure is reduced, resulting in activation of the renin-angiotensin system. Angiotensin II causes selective constriction of the efferent arterioles and raises the pressure gradient across the glomerular capillary membrane. Because of this autoregulatory mechanism, the GFR is maintained and conventional renal scintigraphy may be normal. In these patients, blockade of the conversion of angiotensin I to angiotensin II by administering angiotensin converting enzyme (ACE) inhibitors causes dilatation of the efferent arterioles. This leads to a significant but reversible decrease in GFR that is detectable on renal scintigraphy.

The choice of radiopharmaceutical, ACE inhibitor and technique of examination varies among institutions. Technetium-99m MAG3 is preferred, but technetium 99m-DTPA may be used. Renal scintigraphy is performed approximately 1 hour after oral administration of 25 to 50 milligrams of captopril or 10 to 20 minutes after intravenous injection of 40 micrograms/kg (maximum 2.5 mg) of Enalaprilat. The usual administered dose of captopril in children is 1 mg/kg with a maximum of 50 mg.

Food ingestion within 4 hours prior to captopril administration may decrease absorption and test accuracy. Blood pressure should be measured before administration of the ACE inhibitor and monitored every 10 to 15 minutes. An intravenous line should be kept in place to allow prompt fluid replacement if the patient becomes hypotensive. Furosemide (0.25 mg/kg, maximum 20 mg) given intravenously at the time of tracer administration decreases tracer retention in the collecting systems and may facilitate detection of cortical retention of the tracer. The patient should be well hydrated, especially if furosemide is used.

A common protocol, particularly in children, is to obtain an initial scan without an ACE inhibitor followed by a repeat study after administration of an ACE inhibitor on the same or following day. The study performed without an ACE inhibitor helps to detect subtle ACE inhibitor induced scintigraphic abnormalities. Another protocol is to obtain the study with an ACE inhibitor first. A normal study indicates a low probability for renovascular hypertension and obviates the need for a study without an ACE inhibitor. If the study with an ACE inhibitor is abnormal, a study without an ACE inhibitor is obtained a few days later.

Chronic use of ACE inhibitors may decrease the sensitivity of the test. ACE inhibitors should be discontinued for 3 to 7 days before the test, depending on their half-life. If stopping the patient’s ACE inhibitor is not possible, the study may still be performed.

E. Evaluation of Renal Transplants

Technetium-99m MAG3 or technetium-99m DTPA may be used for evaluating renal transplants. A renal blood-flow study and sequential functional images are obtained using a technique similar to that outlined in section V.B, except that the anterior projection is employed. It is possible to assess the presence or absence of renal blood flow, urine leaks, transplant infarcts, lymphoceles, hematomas, acute tubular necrosis, obstruction, nephrotoxic effect of medications (e.g., cyclosporin A), and renal transplant rejection. Comparison of serial examinations will enhance detection of subtle physiological changes.

F. Renal Cortical Imaging

The preferred agent for renal cortical imaging is technetium-99m DMSA. Alternatively technetium-99m GHA may be used. In most cases, optimal parenchymal imaging can be obtained 1 to 3 hours after injection. By this time, collecting system activity will usually not be present. If there is significant hydronephrosis, delayed images 4 to 24 hours after injection or administration of furosemide may be helpful. If there is no retention of tracer in the collecting system, relative renal function can be calculated. When assessing differential renal mass or function in children with vesicoureteral reflux, the refluxed radiotracer may interfere with accurate quantification. Placement of an indwelling catheter to optimize drainage may be used to minimize this interference. An alternative technique to catheterization is acquisition of additional early DMSA images (first 5 to 10 minutes after injection) for calculating renal differential function. If GHA is used, the differential function may be obtained from the nephrogram phase (1 to 3 minutes postinjection) or on delayed images.

In adults, between 500,000 and 1,000,000 counts per image are desirable. At least 300,000 counts or 5 minutes per image should be used when studying children. A 256 x 256 matrix is preferred. Pinhole (4 mm aperture) images may be useful, especially in infants. Pinhole images should be acquired for a minimum of 100,000 to 150,000 counts or 10 minutes per image. At a minimum, posterior and both posterior oblique views should be obtained. When imaging a "horseshoe" or pelvic kidney, anterior images should be obtained. Single-photon-emission computed tomography (SPECT) imaging may also be performed using these agents. Determination of differential renal function should be performed on the posterior planar image using a parallel hole collimator. Background and depth corrections are optional. Depth correction, which can be accomplished by using the geometric mean, should be considered when there is a major variation or abnormality in the shape or location of the kidneys.

G. Estimation of GFR

The radiopharmaceuticals of choice for estimating GFR are technetium-99m DTPA and iodine-125 iothalamate. Numerous protocols are available, some of which involve imaging. Whichever protocol is used, it is imperative that the technique is meticulous and that the protocol is followed assiduously.

H. Estimation of ERPF

Technetium-99m MAG3 does not give a true ERPF measurement, but it provides a value that can be extrapolated to an ERPF equivalent measurement. Numerous protocols are available, some of which involve imaging. Whichever protocol is used, it is imperative that the technique is meticulous and that the protocol is followed assiduously.

VI. EQUIPMENT

A gamma camera with a parallel-hole collimator is required. When magnification is desired, a converging or pinhole collimator may be used. For adults, a large-field-of-view scintillation camera (400 mm) is desirable, but for children a small-field-of-view camera (250 to 300 mm) is also acceptable. If a large-field-of-view camera is employed in a pediatric patient, "zoom" or pinhole collimation may be used. For most situations using technetium-99m-labeled tracers, low-energy all-purpose/general all-purpose (LEAP/GAP) collimators are sufficient. If renal cortical anatomic detail is desired, a high-resolution collimator will improve image quality, provided the count density is adequate.

For digital acquisition a 64 x 64 acquisition matrix is the minimum necessary, and 128 x 128 may permit more reliable quantification.

SPECT renal imaging using technetium-99m DMSA or technetium-99m GHA may be helpful in some circumstances.

VII. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Guideline for Communication of Diagnostic Imaging Findings.

The report should include the radiopharmaceutical used and the dose and route of administration, as well as any other pharmaceuticals administered, also with dose and route of administration.

VIII. RADIATION SAFETY

Radiologists, medical physicists, imaging technologists, and all supervising physicians have a responsibility to minimize radiation dose to individual patients, to staff, and to society as a whole, while maintaining the necessary diagnostic image quality. This concept is known as "as low as reasonably achievable (ALARA)."

Facilities, in consultation with the radiation safety officer, should have in place and should adhere to policies and procedures for the safe handling and administration of radiopharmaceuticals, in accordance with ALARA, and must comply with all applicable radiation safety regulations and conditions of licensure imposed by the Nuclear Regulatory Commission (NRC) and by state and/or other regulatory agencies. Quantities of radiopharmaceuticals should be tailored to the individual patient by prescription or protocol.

IX. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *Position Statement on QC & Improvement, Safety, Infection Control, and Patient Education* on the ACR web page (http://www.acr.org/guidelines).

Equipment performance monitoring should be in accordance with the ACR Technical Standard for Medical Nuclear Physics Performance Monitoring of Gamma Cameras.

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Suggested Reading (Additional articles that are not cited in the document but that the committee recommends for further reading on this topic)

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*Guidelines and standards are published annually with an effective date of October 1 in the year in which amended, revised, or approved by the ACR Council. For guidelines and standards published before 1999, the effective date was January 1 following the year in which the guideline or standard was amended, revised, or approved by the ACR Council.

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