ACR–ACNM–SPR PRACTICE PARAMETER FOR THE PERFORMANCE OF RENAL SCINTIGRAPHY

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents 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 practitioner considering all the circumstances presented. Thus, an approach that differs from the guidance in this document, 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 this document when, in the reasonable judgment of the practitioner, such course of action is indicated by variables such as the condition of the patient, limitations of available resources, or advances in knowledge or technology after publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document may consider documenting in the patient record information sufficient to explain the approach taken.

The practice of medicine involves the science, and 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 the guidance in this document 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 purpose of this document is to assist practitioners in achieving this objective.

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1 *Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the "ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures (Revised 2008)" sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.*

I. INTRODUCTION

This practice parameter was revised collaboratively by the American College of Radiology (ACR), the American College of Nuclear Medicine (ACNM), and the Society for Pediatric Radiology (SPR) to guide physicians performing renal scintigraphy in adult and pediatric patients.

Renal scintigraphy is used to detect, evaluate, and quantify morphologic and physiologic entities of the kidneys and urinary system using intravenously administered radiopharmaceuticals. Pharmacologic manipulation may enhance the sensitivity and specificity for some entities. Although certain patterns are suggestive of individual disease entities, it is frequently helpful to correlate abnormal findings with clinical information anatomic imaging

(eg, radiographs, computed tomography, magnetic resonance imaging, ultrasound), other radiopharmaceutical imaging, and/or nonimaging examinations.

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

Application of this parameter should be in accordance with the ACR–ACNM–SNMMI–SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures [1].

II. INDICATIONS

1. Indications for renal scintigraphy include, but are not limited to, detection and evaluation (may be quantitative) of: Renal perfusion and function (including differential renal function, which may also be called split or relative function)
2. Distinction between obstructive and nonobstructive hydronephrosis
3. Glomerular filtration rate (GFR)
4. Renal allograft function (to include possible acute tubular necrosis [ATN] and rejection)
5. Renal morphology (to include characterization of pyelonephritis, renal cortical scarring, masses, and congenital/acquired abnormalities)
6. Renovascular hypertension (renal artery stenosis [RAS])
7. Effective renal plasma flow (ERPF)
8. Evaluation of urinary drainage in follow-up of surgically treated urological patients

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR–ACNM–SNMMI–SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures [1].

IV. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for a 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's scope of practice requirements. (ACR Resolution 35 adopted in 2006 – revised in 2016, Resolution 12-b)

IV. SPECIFICATIONS OF THE EXAMINATION

A. Patient Preparation

No special diet is usually required for routine studies. However, evaluation of renovascular hypertension requires no food intake 4 hours prior to angiotensin-converting enzyme (ACE) inhibitor (ACEI) administration (eg, captopril) to increase drug absorption [2]. Moreover, for baseline GFR studies, the patient should be well hydrated but NPO for food, especially protein. Protein loading may induce increased GFR/hyperfiltration [3].

Medication restrictions include discontinuing an ACEI 3 to 7 days prior to renal scintigraphy to improve sensitivity for renovascular hypertension evaluation, although this is not a strict requirement. If the patient's own medications include diuretics, these may be withheld the morning of the study to allow proper hydration. Alternatively, it may be helpful to coordinate timing of renography with the patient's medication schedule to avoid starting the renal scintigraphic examination during a pre-existing diuresis [2,4].

The patient should be well-hydrated before arriving for renal scintigraphy. Upon arrival, an additional 5 to 10 mL/kg of body weight of oral hydration for 30 to 60 minutes or a comparable amount of intravenous fluid (preferably dextrose in water) can be given before imaging. In children, this can be performed during the initial 20-minute renogram [5].

In adult patients with a suspected urinary tract obstruction, the furosemide (F), F+10(sp) method, where sp is sitting position, or other delay time (eg, F+12) may be preferred. Antihypertensive and diuretics should be discontinued 48 hours before examination. An oral fluid load of 400 to 500 mL of water is given 5 minutes after tracer injection. Usually, bladder catheterization is not requested [6].
If the patient has difficulty voiding, bladder catheterization may be considered in consultation with the referring service. In most cases, the catheter should remain in place throughout the examination to allow free drainage. If the patient has a percutaneous nephrostomy tube, indication for the study should be reviewed along with coordination with the ordering provider to determine whether the percutaneous nephrostomy tube should be clamped during the procedure.

The ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation provides useful information on radiation risks to the fetus regardless of source [7]. Information on managing pregnant or potentially pregnant patients undergoing nuclear medicine procedures is available from the International Commission on Radiological Protection [8,9].

Per the Advisory Committee for Medical Use of Isotopes (ACMUI) guidelines, breastfeeding should be interrupted for 24 hours following administration of Technetium-99m (Tc-99m)–labeled radiopharmaceuticals, 3 days for iodine-123-Nal, and stopped completely for iodine-131-Nal [10].

IV. SPECIFICATIONS OF THE EXAMINATION

B. Radiopharmaceuticals

Radiopharmaceuticals used for evaluation of the kidneys may be classified into 3 major categories: tubular secretion, glomerular filtration, and retention in the tubules [11-13].

1. Tc-99m mercaptoacetyl triglycine (MAG3) [11]
    a. Kinetics:
    High extraction renal plasma flow (ERPF) agent due to rapid extraction by tubular cells and secretion into the renal collecting system. Renal uptake is reduced by poor renal perfusion and function but is not affected as severely as with Tc-99m diethylene triamine penta-acetic acid (DTPA) due to both higher extraction (rate is at least twice that of DTPA at 40 to 50%) and a major increase in plasma protein binding (90% versus 2% for DTPA) resulting in a smaller volume of distribution [14].
    b. Indications:
        i. Assess renal perfusion and split function
        ii. Assess urinary tract obstruction
        iii. Assess renovascular hypertension
        iv. Assess renal allograft
        v. Estimate renal plasma flow ERPF
    c. Administered Activity:
        i. Adults: Up to 370 MBq (10 mCi); reduce to 37 to 185 MBq (1-5 mCi) for renal transplant evaluation
        ii. Children with angiographic phase: 5.55 MBq/kg (0.15 mCi/kg); minimum 37 MBq (1 mCi) and Maximum 148 MBq (4 mCi)
        iii. Children without angiographic phase: 3.7 MBq/kg (0.10 mCi/kg); minimum 37 MBq (1 mCi) and Maximum 148 MBq (4 mCi)
2. Tc-99m DTPA
    a. Kinetics:
    Excreted by glomerular filtration and can be used to calculate GFR. Tc-99m DTPA is a marker for the filtration fraction of total renal plasma flow. The extraction fraction is approximately 20% [13].
    b. Indications:

i. Assess renal perfusion and differential glomerular filtration
ii. Assess urinary tract obstruction
iii. Assess renovascular hypertension
iv. Assess renal allograft
v. Estimate GFR

c. Administered Activity:
i. Adults: Up to 555 MBq (10 mCi); reduce to 37 to 185 MBq (1-5 mCi) for renal transplant evaluation
ii. Children: 3.7 to 7.4 MBq/kg (0.1-0.2 mCi/kg). Minimum 37 MBq (1 mCi). Maximum 185 MBq (5 mCi)
iii. GFR without imaging: 7.4 to 18.5 MBq (0.20-0.50 mCi)

3. Tc-99m dimercaptosuccinic acid (DMSA)

a. Kinetics:
Predominantly incorporated into renal tubular cells in the renal cortex with a minor component of glomerular filtration. It is excellent for renal parenchymal imaging including the detection of renal masses and cortical defects, as its long residence time in the parenchyma allows for magnification imaging with a pinhole collimator and/or single-photon emission computed tomography (SPECT) imaging. DMSA is most commonly used in pediatric patients.

b. Indications:
i. Detect and characterize pyelonephritis and/or renal cortical scars
ii. Assess renal shape, size, position and differential function
iii. Detect cortical masses

c. Administered Activity:
i. Adults: Up to 185 MBq (5 mCi)
ii. Children: 1.85 MBq/kg (0.05 mCi/kg). Minimum 18.5 MBq (0.5 mCi). Maximum 100 MBq (2.7 mCi)

IV. SPECIFICATIONS OF THE EXAMINATION

C. General Renal Scintigraphy

Adequate hydration of patients undergoing renal scintigraphy is critical. The patient should void before imaging. For most types of renal scintigraphy, the patient is imaged in the supine position with posterior views acquired. If the patient cannot tolerate supine positioning, examination can also be performed in a seated position. In adult patients, examination can be performed in a seated position. In patients with hydronephrosis, or in follow-up of surgically treated urological patients, more realistic result can be achieved due to the gravity effects. Anterior images should be acquired for pelvic or transplant and horseshoe kidneys. Anterior and posterior images may both be needed if the patient has both ectopic and heterotopic kidneys.

Renal scintigraphy involves serial imaging after intravenous administration of Tc-99m MAG3 or Tc-99m DTPA. A commonly used technique involves dynamic acquisition of 1 to 2 second images for 1 minute (termed perfusion, angiographic, or vascular phase imaging) followed by 60 second images for 20 to 30 minutes (which includes the function or renographic phase imaging uptake, cortical transit, and excretion phases). If evaluation of renal perfusion is not needed, the examination is performed without the first angiographic phase. A final standing static postvoid image of the kidneys and bladder should also be acquired.

Qualitative evaluation of regional renal perfusion, differential function, and cortical transit of radiopharmaceutical can be performed by visual analysis. Quantitative evaluation of cortical function and collecting system drainage is made using regions-of-interest (ROIs) that typically are applied to each whole kidney. A background ROI is placed overlying soft tissue adjacent to each kidney (the most accurate methods entail drawing a C-shaped area lateral to each kidney). Of note, care must be taken in the ROI drawn to exclude hepatic or gallbladder uptake. However, the Patlak-Rutland split function method is preferred by some and agrees better with intrarenal background consisting of blood pooling [15,16]. Differential renal function is calculated based on the relative counts accumulated in each kidney during the initial 1 to 3 minutes after injection of the radiopharmaceutical [17]. Occasionally, it may be helpful to approximate ROI to the renal cortex

and the renal collecting system, although absolute segmentation of cortex and renal collecting system is difficult in most cases. If there is suspected ureteral obstruction or megaureter ROIs may be applied to the ureters as well, either as part of a single large ROI that also includes the kidney or separately. Depending on the ROIs drawn, the time-activity curves will reflect the functional uptake/accumulation and clearance of radiopharmaceutical in the whole kidney, renal cortex, renal collecting system, and/or ureter.

IV. SPECIFICATIONS OF THE EXAMINATION

D. Diuresis Renal Scintigraphy

Diuresis renal scintigraphy can evaluate the severity of urinary tract obstruction and can differentiate an obstructed collecting system from a dilated but nonobstructed collecting system. It also is used for postoperative assessment of the functional and urodynamic results of corrective surgery.

This study is performed by intravenous administration of a loop diuretic (usually furosemide, although other diuretics have been used) in conjunction with renal scintigraphy. Diuretic renography can be performed using a dosage of furosemide that follows the recommendation of the physician performing the procedure. Patients should not have obvious signs/symptoms of hypokalemia, and if there is any doubt, serum potassium levels should be checked. The usual adult diuretic dose of furosemide is 20 to 40 mg injected intravenously. The intravenous dose should be given slowly (1-2 minutes). The pediatric dosage is typically 0.5 to 1 mg/kg body mass, which is more per kilogram body mass than for an adult. A single formula for both adult and pediatric dosing follows Kleiber's law, in this case to mg, where is body mass in kilograms, and the devisor 70 is a prototypical body mass for an adult in kg [18]. However, patients on chronic diuretic therapy likely will be unresponsive to a small dose of furosemide and typically are administered their usual dose of furosemide for diuretic renography. Adjustment of the furosemide dose based on renal function including eGFR should also be taken into consideration. Furosemide dose should be higher in patients with higher degree of chronic kidney disease.

A higher furosemide should be applied in treatment of patients with clinically severe edematous states or higher levels of serum creatinine. However, in a study by Hammarlund et al, the authors administered 40 mg of furosemide to 8 healthy volunteers were given intravenously and orally, demonstrating that after intravenous administration, furosemide concentration in plasma declined quickly in a triexponential manner (half-life for beta-phase of 36 min). The rate of renal excretion was directly proportional to the plasma concentration. The urine flow and chloride excretion rate were used as markers of the effect. Despite a 3-fold difference (28 versus 9 mg/8 hr, $P < .001$) in the cumulative urinary excretion of furosemide between intravenous and postprandial oral administration, no significant difference in the diuretic effect was observed (2-2.2 L/8 hr) [19,20]. In recent years, a reduction in furosemide dosage was observed in nuclear medicine clinical practice. A 20 mg (0.25 mg/Kg) dose of furosemide for diuresis-renography with the F+10(sp) method demonstrated a greater accuracy and an overall better patient compliance as a result of less side effects [6].

Different approaches to diuresis renal scintigraphy are used in clinical practice. According to the position of the patient, we can distinguish 2 testing modalities:

1. Diuresis renography in supine position (common methodology includes F-15, F0, F+2, F+20 methods)
   The time intervals signify the time at which furosemide is administered in relation to the radiopharmaceutical administration. These are characterized by the time of furosemide administration in relation to the time of radiopharmaceutical administration. The most commonly used approach (referred to as F+20) is intravenous administration of furosemide at 20 minutes after the time of radiopharmaceutical injection, with imaging continuing for another 20 to 30 minutes. Other approaches include administering furosemide 15 minutes prior to radiopharmaceutical administration (F-15) or at the time of radiopharmaceutical administration (F-0), or 15 minutes after injection of the radiopharmaceutical (F+15). ROI analyses of the images obtained during the diuretic phase are used for quantitative analysis of collecting system drainage. When using the spine position, test interpretation is based on the visual assessment of renogram curve and acquisition of a late scan after walking and voiding.

2. Diuresis renography in sitting position (F+10(sp) method)
   This approach may be preferable in adult patients with a suspected urinary tract obstruction and for the follow-up of surgically treated urological patients. Using the F+10(sp) method evaluates patient seated in an imaging chair, which offers arm support to prevent involuntary movement. 99mTC-MAG3 is injected, and a dynamic scan is performed for 20 minutes. At 5 minutes, the patient drinks 400 to 500 mL of water. At 10 minutes, the patient receives 20 mg of furosemide as an IV bolus during dynamic imaging acquisition. Diagnosis is based on the measurement of outflow indices when evaluated in a gravity-favorable condition: diuretic half-time (normal value <8 min) and 20 min/peak ratio (normal value <0.25).

   In children, and particularly in neonates, the natural history of prenatal hydronephrosis and possible urinary tract obstruction can be variable. Repeated renal scintigraphy may be needed to detect gradual improvement or worsening of urinary tract drainage over time. In neonates, renal function continues to mature after birth, and renal immaturity during the first few months after birth may delay uptake and clearance of tubular radiopharmaceuticals. Ideally, renography will be delayed until at least 3 months of age to allow for renal maturation. If this is not possible, then the diuretic renogram must be interpreted in the context of renal immaturity.

IV. SPECIFICATIONS OF THE EXAMINATION

E. Estimation of GFR and ERPF

The radiopharmaceutical used for estimating GFR is Tc-99m DTPA. The radiopharmaceutical used for estimating ERPF is TC-99m MAG3, which correlates strongly with that of 131I-OIH [21]. Although commonly equated to ERPF, MAG3 is more properly a measurement of tubular function. Numerous protocols are available, some of which involve imaging and others of which involve serial blood draws [11,22-25]. Whichever protocol is used, it is imperative that the technique is meticulous and that the protocol is followed assiduously.

IV. SPECIFICATIONS OF THE EXAMINATION

F. Evaluation of Renal Allografts

Renal scintigraphy can be an assessment tool for renal allograft dysfunction and as a postoperative screening examination for surgical complications. Renal scintigraphy is performed as outlined in section IV.C. above using Tc-99m MAG3 or Tc-99m DTPA, although Tc99m-MAG3 is preferred in patients with poor renal function. Note that an anterior projection centered over the lower abdomen and pelvis must be used given typical allograft positioning within the anterior pelvis.

It is possible to assess the presence or absence of renal perfusion, cortical infarcts, acute tubular necrosis (ATN), collecting system obstruction, urine leaks, nephrotoxic effect of medications (eg, cyclosporine A), and rejection [26]. An important goal is differentiating between ATN and rejection. ATN typically shows relatively preserved renal perfusion with diminished but progressively increasing cortical uptake with limited to no excretion into the collecting system. Allograft rejection may show both diminished perfusion and function. Comparison of serial examinations will enhance detection of subtle physiological changes [27].

IV. SPECIFICATIONS OF THE EXAMINATION

G. Renal Morphology

Renal scintigraphy can help detect and evaluate the renal cortex (including characterization of pyelonephritis and cortical scarring), renal masses or other renal parenchymal defects, and congenital or acquired abnormalities. The focus here will be on renal cortical imaging.

The preferred radiopharmaceutical for renal cortical imaging is TC-99m DMSA. In most cases, optimal parenchymal imaging can be obtained 2 to 4 hours after radiopharmaceutical administration. If there is significant hydronephrosis, delayed imaging at 24 hours or administration of furosemide prior to delayed imaging may be helpful. Delayed imaging may also be necessary if there is poor renal function. If there is no retention of radiopharmaceutical in the collecting system, relative renal function can be calculated. When assessing

differential renal function in children with vesicoureteral reflux, note that refluxed radiopharmaceutical may interfere with accurate quantification [28].

In adults, between 500,000 and 1,000,000 counts per static image are desirable. At least 300,000 counts or 5 minutes per image should be used when imaging children [23]. A 256 × 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. SPECT imaging also may be performed and has been shown to have greater sensitivity in detecting smaller cortical defects in pediatric patients with pyelonephritis [29,30].

Functional renal tubular cell mass can be calculated using geometric mean of the anterior and posterior renal regions [31].

Of note, if DMSA is not available, MAG3 can be used to assess cortical morphology; however, given the limited cortical residence time when compared to DMSA, an image stack consisting of the first 1 to 2 minutes of dynamic imaging following the angiographic phase must be used. This necessitates anterior imaging with a parallel hole collimator and does not provide the same degree of detail as pinhole collimator images with DMSA.

IV. SPECIFICATIONS OF THE EXAMINATION

H. Captopril (Angiotensin-Converting Enzyme Inhibitor or ACEI) Renal Scintigraphy

Due to increased use of CT and MR angiography, the utilization of ACEI renal scintigraphy has diminished.

Imaging assessment for renovascular hypertension, including scintigraphy, is most appropriate in patients with a high index of suspicion. Patients with a low index of suspicion usually have essential hypertension that can be well controlled medically, and in these patients, imaging is not generally indicated.

Renovascular hypertension is caused by hemodynamically significant stenosis of the main renal artery or one of its branches. Most hypertension is essential (idiopathic), with less than 5% having a demonstrated renovascular etiology. The prevalence of renovascular hypertension is somewhat higher in patients with risk factors that include severe hypertension and end-stage renal disease. Note that RAS may be present in these patients and still not etiology of the patient's hypertension. Thus, the goal of ACEI renography is to identify the subgroup of patients in whom hypertension is due to RAS and who could potentially respond to an intervention, such as revascularization [4].

In the presence of hemodynamically significant RAS, renal perfusion pressure is reduced, activating the renin-angiotensin system as compensation. Angiotensin II causes selective constriction of the efferent arterioles and raises the pressure gradient across the glomerular capillary basement membrane. Because of this autoregulatory mechanism, the GFR is maintained, and conventional renal scintigraphy may be normal. In these patients, administering an ACEI causes dilatation of the efferent arterioles, blunting this compensation. This leads to a significant but reversible decrease in GFR that is detectable on renal scintigraphy.

The choice of radiopharmaceutical, ACEI, and technique of examination varies among institutions. Tc-99m MAG3 is preferred, given its reliable active excretion into the tubules and limited filtration, but Tc-99m DTPA may be used. Renal scintigraphy is performed approximately 1 hour after oral administration of 25 to 50 mg of captopril or 10 to 20 minutes after intravenous injection of 40 micrograms/kg (maximum 2.5 mg) of enalaprilat. The usual administered dosage of captopril in children is 1 mg/kg, with a maximum of 50 mg. Captopril renography is performed first, and if there is more than 5% functional discrepancy between the two kidneys, the renal scan without captopril is repeated the following day. Renal scintigraphy with and without enalaprilat can be performed consecutively on the same day.

Blood pressure should be measured before administration of the ACEI and monitored every 10 to 15 minutes. If a diuretic is used, 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

radiopharmaceutical administration decreases radiopharmaceutical retention in the collecting systems and may facilitate detection of cortical retention of the radiopharmaceutical. The patient should be well hydrated, especially if furosemide will be used [2].

A commonly used protocol is to perform a baseline scan without prior ACEI administration, followed (on the same or following day) by a second scan performed after administration of an ACEI [4,32]. Comparison of the 2 scans helps to detect subtle scintigraphic abnormalities produced by ACEI. An alternative protocol is to perform the first scan after administration of an ACEI [4]. A normal examination indicates a low probability for renovascular hypertension and obviates the need for a baseline examination without an ACEI. If the examination with an ACEI is abnormal, a baseline examination is performed on a following day. If possible and safe, ACEI medication should be stopped approximately 3 days prior to the study.

With the use of intravenous enalaprilat and Tc-99m MAG3 (but not Tc-99m DTPA), both the baseline and post-ACEI scans can be completed within 60 to 90 minutes. After administration of 1 to 3 mCi of Tc-99m MAG3, a baseline scan is performed for 20 to 30 minutes. Subsequently, 40 mg/kg (maximum 2.5 mg) of enalaprilat is administered intravenously. Ten to twenty minutes later, 8 to 10 mCi of Tc-99m MAG3 is administered, and the second scan is performed for 20 to 30 minutes [33].

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [34].

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

VI. EQUIPMENT SPECIFICATIONS

Equipment performance monitoring should be in accordance with the ACR–AAPM Technical Standard for Nuclear Medical Physics Performance Monitoring of Gamma Cameras [35].

A. Equipment Specifications

A gamma camera with a parallel-hole collimator is required. When magnification is desired, a pinhole collimator may be used. For adults, a large-field-of-view gamma camera (400 mm) is desirable, but for children, a small-field-of-view camera (250 to 300 mm) is acceptable. If a large-field-of-view camera is used in a pediatric patient, "zoom" or pinhole collimation may be used. For Tc-99m–labeled radiopharmaceuticals, a low-energy high resolution or general purpose collimator is preferred for dynamic imaging. For static imaging, a low-energy high-resolution, low-energy ultrahigh-resolution, or pinhole collimator is preferred [17,36].

For digital acquisition, a 128 × 128 matrix is the minimum necessary, but a 256 × 256 matrix may be preferred. SPECT (or SPECT/CT in adults) renal imaging using Tc-99m DMSA may be helpful in some circumstances.

B. Equipment Processing

Processing includes correct drawing of ROIs, background correction, generation of time-activity curves, and other quantitative indices (which may include relative perfusion, split function, time-to-peak or Tmax, half-life, diuretic half-time, 20 minute/maximum count ratio, postvoid renal counts, and camera renal clearance rates) [13,17].

VII. RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, non-physician radiology providers**,** radiologic technologists, and all supervising physicians have a responsibility for safety in the workplace by keeping radiation exposure to staff, and to society as a whole, "as low as reasonably achievable" (ALARA) and to assure that radiation doses to individual patients are appropriate, taking into account the possible risk from radiation exposure and the diagnostic image quality necessary to achieve the clinical objective. All

personnel who work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection, application of dose constraints and limits) and the principles of proper management of radiation dose to patients (justification, optimization including the use of dose reference levels). https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1775_web.pdf

Nationally developed guidelines, such as the ACR's Appropriateness Criteria®, should be used to help choose the most appropriate imaging procedures to prevent unnecessary radiation exposure.

Facilities should have and adhere to policies and procedures that require ionizing radiation examination protocols (radiography, fluoroscopy, interventional radiology, CT) to vary according to diagnostic requirements and patient body habitus to optimize the relationship between appropriate radiation dose and adequate image quality. Automated dose reduction technologies available on imaging equipment should be used, except when inappropriate for a specific exam. If such technology is not available, appropriate manual techniques should be used.

Additional information regarding patient radiation safety in imaging is available from the following websites – Image Gently® for children (www.imagegently.org) and Image Wisely® for adults (www.imagewisely.org). These advocacy and awareness campaigns provide free educational materials for all stakeholders involved in imaging (patients, technologists, referring providers, medical physicists, and radiologists).

Radiation exposures or other dose indices should be periodically measured by a Qualified Medical Physicist in accordance with the applicable ACR Technical Standards. Monitoring or regular review of dose indices from patient imaging should be performed by comparing the facility's dose information with national benchmarks, such as the ACR Dose Index Registry and relevant publications relying on its data, applicable ACR Practice Parameters, NCRP Report No. 172, Reference Levels and Achievable Doses in Medical and Dental Imaging: Recommendations for the United States or the Conference of Radiation Control Program Director's National Evaluation of X-ray Trends; 2006, 2009, amended 2013, revised 2023 (Res. 2d).

VIII. 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 Quality Control & Improvement, Safety, Infection Control, and Patient Education* on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

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