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SNMMI Procedure Standard/EANM Practice Guideline for Diuretic Renal Scintigraphy in Adults With Suspected Upper Urinary Tract Obstruction 1.0

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Preamble

The Society of Nuclear Medicine and Molecular Imaging (SNMMI) is an international scientific and professional organization founded in 1954 to promote the science, technology, and practical application of nuclear medicine. Its 18,000 members are physicians, technologists, and scientists specializing in the research and practice of nuclear medicine. In addition to publishing journals, newsletters, and books, the SNMMI also sponsors international meetings and workshops designed to increase the competencies of nuclear medicine practitioners and to promote new advances in the science of nuclear medicine. The European Association of Nuclear Medicine (EANM) is a professional nonprofit medical association that facilitates communication worldwide between individuals pursuing clinical and research excellence in nuclear medicine. The EANM was founded in 1985.

The SNMMI/EANM will periodically define new procedure standards and guidelines for nuclear medicine practice to help advance the science of nuclear medicine and to improve the quality of service to patients. Existing standards and guidelines will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated. Since February 2014, the SNMMI guidelines have been referred to as procedure standards. Any practice guideline or procedure guideline published before that date is now considered an SNMMI procedure standard.

Each standard and guideline, representing a policy statement by the SNMMI/EANM, has undergone a thorough consensus process in which it has been subjected to extensive review. The SNMMI/EANM recognizes that the safe and effective use of diagnostic nuclear medicine imaging requires specific training, skills, and techniques, as described in each document.

The EANM and SNMMI have written and approved these standards and guidelines to promote the use of nuclear medicine procedures with high quality. These standards and guidelines are intended to assist practitioners in providing appropriate nuclear medicine 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 SNMMI/EANM cautions against the use of these procedure standards and 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 medical professionals taking into account the unique circumstances of each case. Thus, there is no implication that an approach differing from the standards or guidelines, standing alone, is 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 standards or 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 standards or guidelines.

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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 standards or guidelines will not ensure 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 standards or guidelines is to assist practitioners in achieving this objective.

I. Introduction

Obstruction to urinary outflow may lead to obstructive uropathy (dilatation of the calices, pelvis, or ureters) and obstructive nephropathy (damage to the renal parenchyma). The goal of intervention in patients with suspected obstruction is to preserve renal function because a high-grade obstruction to urine outflow can rapidly lead to a nonfunctional kidney.[1] Suspicion of urine outflow obstruction is usually based on clinical findings, the incidental detection of a dilated renal collecting system, or diagnosis of previous obstruction in a patient referred for follow-up. Although the incidence of obstructive uropathy in adults has not been well defined, the U.S. Nationwide Inpatient Sample reported urinary obstruction in 0.1% of all discharge diagnoses, primarily in men older than 65 years.[2]

Diuretic renography is a noninvasive, widely available test that can evaluate renal function and urine transit in a single procedure. This test is based on a high endogenous rate of urine flow stimulated by the administration of furosemide. Interpretation is based on renal function and washout of the radiopharmaceutical from the collecting system of the upper urinary tract. Greater detail on specific aspects of renal scintigraphy can be found in recent reviews and will be available in an upcoming SNMMI procedure standard/EANM practice guideline for renal scintigraphy in adults.[3,4]

II. Goals

The purpose of this procedure standard/guideline is to assist nuclear medicine practitioners in recommending, performing, interpreting, and reporting the results of diuretic renal scintigraphy in the setting of suspected renal obstruction in adults. The goals of diuretic renal scintigraphy are to diagnose or exclude the presence of renal obstruction and target the site for intervention. Diuretic renography in the pediatric population has been addressed by SNMMI in a procedure standard for diuretic renography in children and by the EANM in a guideline for standard and diuretic renography in children.[5,6]

III. Definitions

Obstruction is defined as a level of resistance to urine outflow that, if untreated, will lead to loss of function.[7] An obstruction may be high, intermediate, or low grade. A high-grade obstruction is usually acute, often presents with persistent parenchymal uptake and an empty pelvis, and rapidly leads to loss of function.[1] The intermediate and low grades of obstruction are much more common and lead to a more gradual loss of renal function. The term *partial obstruction* does not have a uniformly accepted meaning and should be avoided; in particular, this term should not be used to express uncertainty regarding the presence or absence of obstruction.

IV. Common Clinical Indications

There are several common clinical indications for diuretic renal scintigraphy: to measure the relative function of a possibly obstructed kidney in order to determine whether renal function is compromised and establish a baseline for monitoring any future loss of function that might require intervention; to determine whether renal obstruction is present in a patient who has signs or symptoms of obstruction; and to determine whether renal obstruction is present in an asymptomatic patient for whom hydronephrosis was detected on prior imaging.

V. Qualifications and Responsibilities of Personnel

In the United States, see the SNMMI Procedure Standard for General Imaging. In Europe, the certified nuclear medicine physician who performed the study and signed the report is responsible for the procedure, according to national laws and rules.

VI. Procedure or Specifications of the Examination

A. Study request. The study request should ideally specify the questions to be answered, provide a relevant history, and give instructions on the clamping of nephrostomy tubes if they are present. If the request is vague or incomplete, the referring physician needs to be contacted to provide clarification. The interpreting physician should review all available pertinent clinical, laboratory, and radiologic data before performing the study. This information may include the presence of clinical signs of obstruction, such as flank pain, reduced urine volume, and increased urgency and frequency of urination; the most recent serum creatinine level; whether the patient is pregnant or breastfeeding; current diuretic medications and dosages; fluid restrictions; medication allergies; the results of prior imaging procedures evaluating the kidneys and ureters; and relevant urologic procedures or surgeries (nephrostomy

tubes and whether clamping should occur, ureteral stents, bladder catheters, urinary diversion, renal transplant, and location).

B. Patient information. Information describing the study and needed hydration should be provided to outpatients before arrival.

C. Hydration. Unless there is a contraindication, the patient should be instructed to arrive well hydrated and should receive an additional oral fluid load of 5-10 mL/kg of body weight 30-60 minutes before the procedure.[8] If intravenous hydration is clinically indicated, it can be accomplished with a volume of fluid comparable with the amount of water recommended for oral hydration. Intravenous fluid consisting of dextrose in water is recommended as the goal is not volume replacement but maximization of urine output.

D. Diet. No special diet is required. Fasting before the study should be avoided as it may result in a relatively dehydrated patient.

E. Chronic diuretic administration. If receiving chronic diuretics, the patient should hold them the morning of the study to support adequate hydration.

F. Pregnancy. If the patient is pregnant or thinks she may be pregnant, the nuclear medicine physician should counsel her regarding the necessity of the study and radiation risk before she arrives for the test.

G. Breastfeeding. Interruption of breastfeeding is not required. Using 1 mSv as the estimated threshold dose to the infant, Stabin and Breitz recommend no cessation of breastfeeding for ^{99m}Tc-diethylenetriaminepentaacetic acid (DTPA), ^{99m}Tc-mercaptoacetyltriglycine (MAG3), or ^{123}I-orthoiodohippurate.[9] The EANM Task Group Explaining Risks agreed that interruption of breastfeeding was not essential but that the mother could be reassured by a 4-hour interruption for ^{99m}Tc-MAG3 and a 12-hour interruption for ^{99m}Tc-DTPA and ^{123}I-orthoiodohippurate.[10] Publication 106 of the International Commission on Radiological Protection likewise recommends no cessation of breastfeeding, although discarding one meal of expressed milk after imaging could be considered a conservative alternative.[11] With the availability of suitable alternatives, ^{131}I-orthoiodohippurate should not be administered to women who are pregnant or breastfeeding.

H. Injection technique. It is essential to avoid infiltration of the tracer or furosemide. Infiltration can be minimized by injecting through an established cannula rather than by direct injection into a vein.

I. Safety of furosemide. Furosemide is a nonantibiotic sulfonamide, leading to questions about its safety in patients reporting a reaction to sulfonamide antibiotics. Although there is an association between hypersensitivity after receipt of sulfonamide antibiotics and a subsequent allergic reaction after receipt of a sulfonamide nonantibiotic, this association appears to be due to a general predisposition to allergic reactions rather than to any specific cross-reactivity with sulfonamide-based drugs.[12] The immunologic determinant of IgE-mediated immunologic responses to sulfonamide antibiotics is the N1 heterocyclic ring; this N1 heterocyclic structure is not present in nonantibiotic sulfonamides such as furosemide[13]; consequently, in the absence of the N1 heterocyclic ring, cross-reactivity is not expected. The lack of cross-reactivity between sulfonamide antibiotics and sulfonamide nonantibiotics is supported by recent reviews.[12-15]

To put the risk of an allergic reaction from furosemide into clearer context, the risk of an allergic reaction after receipt of a sulfonamide nonantibiotic was higher among patients with a history of hypersensitivity to penicillins than among patients with a history of hypersensitivity to sulfonamide antibiotics.[12] In fact, most prescribers do not view the use of sulfonamide nonantibiotics as problematic in the sulfonamide-allergic patient.[15] In keeping with this point of view, most members of the standards/guideline committee do not check for a history of allergic reactions to sulfonamide antibiotics, and furosemide is administered as a bolus over a few seconds; based on a combined experience of several thousand patients using this approach, no allergic responses to furosemide have been observed by the members of the writing committee.

J. Bladder catheterization. A bladder catheter should be inserted after consultation with the referring physician if the patient is anticipated to have difficulty voiding. If a bladder catheter is required or already in place, it should be allowed to drain freely, as free drainage facilitates assessment of upper tract drainage. If there has been recent bladder surgery, free drainage is essential to avoid the risk of leakage through the surgical incision.

VII. Radiopharmaceutical Choice

The radiopharmaceuticals available for assessment of renal function and anatomy can be grouped into three broad categories: the first is those filtered by the glomerulus, the second is those primarily secreted by the renal tubules via the organic anion transporter 1,[16] and the third is those retained in the renal tubules via proximal tubule receptor-mediated endocytosis from the glomerular filtrate.[17] Adult and pediatric consensus groups recommend tubular agents (^{99m}Tc-MAG3, ^{99m}Tc-L,L-ethylenedicysteine, or ^{123}I-orthoiodohippurate) for diuretic renography because tubular tracers are much more efficiently extracted by the kidney than ^{99m}Tc-DTPA, and washout is therefore easier to evaluate.[16,18-20] Because of parenchymal retention, neither ^{99m}Tc-glucoheptonate nor ^{99m}Tc-dimercaptosuccinic acid is an appropriate tracer for diuretic renography to evaluate suspected obstruction.

A. ^{99m}Tc-MAG3 (tubular secretion). ^{99m}Tc-MAG3 is highly protein-bound and is removed from the plasma primarily by the organic anion transporter 1 located on the basolateral membrane of the proximal renal tubules.[16,19,20] The extraction fraction of ^{99m}Tc-MAG3 is 40%-50%,[20] more than twice that of ^{99m}Tc-DTPA. Because of its more efficient extraction, ^{99m}Tc-MAG3 is preferred over ^{99m}Tc-DTPA in patients with suspected obstruction and impaired renal function.[5,6,21-24]

B. ^{99m}Tc-L,L- and -D,D-ethylenedicysteine (tubular secretion). ^{99m}Tc-L,L and -D,D-ethylenedicysteine are enantiomers. Both are excellent renal radiopharmaceuticals, with clearances

slightly higher than that of ^{99m}Tc-MAG3.[25-28] Although ^{99m}Tc-D,D-ethylenedicysteine is cleared more rapidly than ^{99m}Tc-L,L-ethylenedicysteine,[26] ^{99m}Tc-L,L-ethylenedicysteine was first described and is now available as a kit formulation in several countries; it is an acceptable radiotracer for diuretic renography.

C. ^{123}I- and ^{131}I-orthoiodohippurate (tubular secretion). ^{123}I- and ^{131}I-orthoiodohippurate are cleared primarily via organic anion transporter 1 in the proximal tubules, although a small component is filtered by the glomeruli. The clearance of orthoiodohippurate is approximately 500-600 mL/min in subjects with normal kidneys.[19] The poor imaging characteristics of ^{131}I, the potential of ^{131}I-orthoiodohippurate for delivering a high radiation dose, and the unfavorable logistics resulting from the relatively short half-life of ^{123}I have caused these radiopharmaceuticals to fall out of favor.[29,30]

D. ^{99m}Tc-DTPA (glomerular filtration). ^{99m}Tc-DTPA is the only radiopharmaceutical available for renal imaging that is filtered purely by the glomerulus; consequently, it is the only radiopharmaceutical that can be used both to image the kidney and to measure glomerular filtration rate.[18] In healthy subjects, the extraction fraction of ^{99m}Tc-DTPA (the percentage of the tracer extracted with each pass through the kidney) is approximately 20%; this extraction fraction is relatively low compared with the extraction fraction of tubular tracers (41%-86%).[19,20,31]

VIII. Acquisition

A. Collimation, pixel size, and acquisition parameters. Images with ^{99m}Tc agents should be acquired using a gamma camera with a low-energy all-purpose or low-energy high-resolution collimator. A large-field-of-view gamma camera with a low-energy all-purpose collimator is preferred because the higher counting rates reduce the noise for quantitative measurements using cortical and whole-kidney regions of interest (ROIs) relative to a low-energy high-resolution collimator; the reduction in noise more than compensates for the slight loss of resolution, particularly for studies generating quantitative indices with parenchymal ROIs. If a low-energy all-purpose collimator is not available, a low-energy high-resolution collimator is an acceptable alternative. A medium-energy collimator may be preferable for ^{123}I-orthoiodohippurate when quantitation is important.

Acquisition should begin before tracer injection, with time zero defined as the peak of the heart curve or time of arrival of the bolus in the kidney; bolus arrival in the kidney can be determined by back extrapolation of the initial phase of the renogram curve. Images should be acquired dynamically using serial 10-second frames, with the preferred pixel size ranging from 2 to 4 mm. To enhance the reproducibility and accuracy of quantitative measurements that depend on a defined starting point, some software programs use a 2-second framing rate for the first few minutes to more precisely determine time zero.

B. Patient position. The study should be acquired with the patient supine and the camera at the patient's back for normally positioned kidneys or anteriorly over the pelvis for a transplanted kidney. The supine position allows a more accurate estimate of relative renal function as the kidneys are more likely to lie at the same depth[32]; however, drainage in the supine or prone position may be delayed, and a postvoid image at the conclusion of the acquisition is essential to evaluate gravity-dependent drainage (see Section G). Patients may be imaged while seated to avoid physiological stasis in the collecting system, but nephroptosis has been observed in 22% of kidneys when seated patients are imaged.[33] A change in kidney position due to nephroptosis can lead to a difference in the measurement of relative uptake due to differences in attenuation rather than differences in relative function. A possible advantage of the seated position, however, may be the detection of obstruction in a ptotic kidney. Scanning the patient in both supine and erect positions may be useful if nephropexy surgery is planned.

C. Voiding immediately before the examination. The patient should void immediately before the examination to minimize the possibility of terminating the study prematurely and to avoid delay of upper tract emptying due to a full bladder.[21]

D. Acquisition protocol and timing of diuretic administration. Multiple protocols have been used for diuretic renal scintigraphy with the patient in the supine position; they differ in the timing of furosemide administration and in the number of acquisitions (one or two). No consensus exists regarding the timing of furosemide and the number of acquisitions; however, consensus does exist on the need to include a postvoid image when there is suspicion of obstruction. The timing of furosemide administration includes the F – 15, F = 0, F + 2, F + 5, F + 10, F + 20, F + 30, and Fmax protocols where the furosemide is administered 15 minutes before tracer administration (F – 15); at the same time as tracer administration (F = 0); 2, 5, 10, 20, or 30 minutes after tracer administration, and when the activity in the collecting system appears to have reached a maximum (Fmax).[21,34-43]

The F – 15 protocol is based on the observation that the average rate of urine flow 15-18 minutes after furosemide administration is greater than that at 3-6 minutes (24 mL/min vs 20.5 mL/min, respectively).[44] Administering the tracer at the time of maximum diuresis (F – 15) is reported to allow better discrimination between obstructed and nonobstructed kidneys.[44] A disadvantage of the F – 15 protocol is that a percentage of patients (as high as 30% in one series) will not complete the study because of a need to void before the acquisition is complete.[34] Results comparable with or superior to those obtained with the F – 15 approach have been reported by administering furosemide 10 minutes after tracer injection with the patient imaged in a seated position (F + 10sp) to facilitate gravity-dependent drainage.[33]

The Santa Fe Consensus Report recommended a 35-minute acquisition with furosemide administered 20 minutes into the study.[21] A single 35-minute acquisition can be divided into two separate acquisitions. The first is a 20- to 30-minute baseline acquisition, after which the patient assumes an upright posture and voids. If the results of the baseline study are normal, obstruction can be excluded and the furosemide acquisition can be omitted. If the baseline study has

abnormal or questionable results, a second 20-minute acquisition must be performed after intravenous administration of furosemide.

In conclusion, the F = 0 protocol is most convenient and minimizes imaging time, whereas the F – 15 study and F + 10sp are reported to allow better discrimination between obstructed and nonobstructed kidneys. The F + 20, F + 30, Fmax, and dual-acquisition protocols allow observation of natural urinary drainage kinetics. In addition, these protocols allow direct evaluation of tracer washout from a dilated collecting system and may allow exclusion of obstruction in a poorly functioning kidney, whereas an F – 15 or F = 0 protocol may simply demonstrate rising parenchymal activity without showing tracer in the collecting system, a pattern that may fail to distinguish between reduced function with obstruction and reduced function without obstruction. Each protocol has its advocates, but all appear to give acceptable results in most patients.[3,21,33,34,36-43]

E. Administered activity and the radionuclide angiogram. Renal scans are sometimes performed after intravenous injection of approximately 370 MBq (10 mCi) of ^{99m}Tc-MAG3 or ^{99m}Tc-DTPA. Administration of activities in the range of 370 MBq may be required to obtain sufficient counts to visualize the initial bolus as it transits the aorta and kidneys (radionuclide angiogram) or to calculate quantitative flow indices.[45-47] However, except for the evaluation of renal transplants, neither 2-second flow images nor quantitative flow calculations obtained in the first few seconds after injection have been shown to contribute to the evaluation of relative function, suspected obstruction, or renovascular hypertension.[45-48] An administered activity of 370 MBq (10 mCi) is unnecessarily high for almost all applications, and a range from 37 to 185 MBq (1-5 mCi) is preferred to avoid unnecessary exposure of patients to radiation.[8,18,21,48-51]

E. Dose of furosemide. The standard adult dose of furosemide is 0.5 mg/kg or 40 mg.[21,51] In adults with normal renal function, 40 mg of furosemide produces maximal diuresis, with urine flow rates reaching approximately 20 mL/min within 3-6 minutes.[41,44,52,53] In fact, a 20- to 30-mg dose of furosemide usually produces adequate diuresis in a young adult with normal renal function. Patients with impaired renal function, however, may not have an adequate diuretic response to 40 mg of furosemide and the dose may need to be increased to achieve an adequate diuretic response.[52]

Furosemide is highly protein-bound and is not filtered by the glomerulus; it is secreted into the proximal tubule via the same organic anion transporter 1 as is ^{99m}Tc-MAG3 and travels in the tubular fluid to reach its site of action in the thick ascending loop of Henle.[19,52] In the dual-acquisition protocol, ^{99m}Tc-MAG3 clearance can be measured at the time of the baseline study. If the ^{99m}Tc-MAG3 clearance is reduced by 50%, secretion of furosemide into the tubular lumen will also be reduced by about 50% as furosemide and ^{99m}Tc-MAG3 share the same transporter. Consequently, the administered dose of furosemide will need to be doubled to achieve the same tubular concentration of furosemide that is obtained in a patient with normal renal function. A decision to increase the dose of furosemide can also be based on the level of serum creatinine. An abnormal serum creatinine level usually implies at least a 50% decrease in glomerular filtration rate. Although ^{99m}Tc-MAG3 is not filtered, its clearance usually decreases in proportion to a decrease in glomerular filtration rate.

In summary, a decrease in ^{99m}Tc-MAG3 clearance or an abnormal level of serum creatinine may indicate the need to increase the dose of furosemide to obtain an adequate diuretic response in the affected kidney. Because no diuretic renography studies have compared 40 mg of furosemide with higher doses in patients with reduced function of one or both kidneys, no specific recommendations can be made on the relationship between the dose of furosemide and serum creatinine level or ^{99m}Tc-MAG3 clearance. A reasonable approach is to double the dose of furosemide to 80 mg for patients with a creatinine level that is elevated or a ^{99m}Tc-MAG3 clearance rate that is reduced by 50% or more. Consideration may be given to increasing the dose to above 80 mg in patients with severely compromised function. The safety of furosemide is discussed in Section VI.I.

F. Bumetanide. If furosemide is not available, bumetanide is an acceptable alternative; like furosemide, bumetanide requires delivery into the tubular fluid for access to its site of action. One milligram of bumetanide is equivalent to approximately 40 mg of furosemide.[54]

G. Gravity-assisted drainage and postvoid images of the kidney and bladder. Drainage from the renal pelvis can be facilitated by maximizing the pressure differential between the renal pelvis and bladder. An upright posture and an empty bladder maximize the pressure differential between the renal pelvis and bladder and facilitate urine drainage into the bladder.

At the conclusion of the acquisition, a static postvoid image of the kidney should be obtained with the patient in the same position as for the prevoid images. The postvoid image should be displayed using the same time interval as the prevoid images to facilitate evaluation of drainage and comparison with the prevoid images.

H. Residual urine volume. At the time of the study, residual urine volume can be measured on the basis of counts in pre- and postvoid ROIs over the bladder and measurement of the voided volume, using the following formula: residual urine volume = (voided volume)(prevoid counts)/(prevoid counts – postvoid counts).[55] Patients should walk around for several minutes to facilitate gravity-assisted drainage from the kidneys to the bladder before voiding. This period of upright posture will minimize the error resulting from residual urine draining from the pelvis into the bladder after the patient voids and before the postvoid image. This measurement may also detect unsuspected urinary retention.

I. Urine flow rate. The rate of urine flow can be calculated by dividing the voided volume at the conclusion of the study by the interval between the time of prestudy voiding and the time of poststudy voiding.

IX. Image Processing

A. Whole-kidney ROIs and renogram curves. Time-activity curves can be generated after placement of ROIs. The

whole-kidney ROI is placed around the entire kidney, including the renal pelvis, and is required to measure relative tracer uptake in each kidney. The renogram curve generated from the whole-kidney ROI will be affected by retention of tracer in both the parenchyma and the pelvis. Tracer retention may occur in pathologic states such as diabetic nephropathy or obstruction but may also occur in nonpathologic states such as a non–obstructed dilated collecting system or mild dehydration.

B. Cortical (parenchymal) ROIs and renogram curves. To better assess parenchymal function, ROIs can be restricted to the renal cortex, excluding any retained activity in the renal pelvis or calyces. The function of the cortical curve is to evaluate parenchymal function by displaying the transit time through the cortex without contamination by activity in the collecting system. Parenchymal ROIs are drawn specifically to exclude activity in the pelvis and calyces, not to have equal areas.[56] Consequently, it is the shape of the cortical renogram that is important, not the absolute height. A difference in relative height between cortical curves does not indicate relative cortical function but is due simply to a difference in size between the relative cortical ROIs; a larger cortical ROI will have more counts than a smaller one.

C. Pelvic ROIs. For the diuretic portion of F + 20 and dual-acquisition studies, renogram curves and quantitative measurements can be derived from restricting placement of the ROI to activity in the renal pelvis and collecting system rather than placing the ROI over the whole kidney. Pelvic ROIs that only include retained activity in the collecting system and that avoid the parenchyma allow better assessment of the response to furosemide than do whole-kidney ROIs.[7,24,43,57,58]

D. Background correction. Background consists of radiotracer present in blood, the interstitial space of the kidney, and tissues anterior and posterior to the kidney. For tracers with a low extraction fraction, such as ^{99m}Tc-DTPA, the background counts during the second to third minutes after injection can be as high as 50%-80% of the total activity in the renal ROI, particularly in patients with reduced renal function.[8] To correct for these nonrenal counts in the renal ROI, background correction needs to be performed. In calculations of relative renal uptake, a perirenal background ROI slightly separated from the whole-kidney ROI to avoid scatter from the latter is preferred over a background ROI superior, medial, or inferior to the whole-kidney ROI. Counts in the background ROI must be normalized to the kidney ROI.[8,59] Automated background assignments that track the kidney ROI reduce processing time and enhance reproducibility. If the background ROI includes tracer that subsequently accumulates in the renal pelvis, background may be oversubtracted in the latter part of the study, leading to errors in generating quantitative drainage parameters. Further details on background correction methods and quality control of quantitative measurements of renal function are available in a consensus report from the International Scientific Committee of Radionuclide in Nephrourology.[8]

E. Relative function. The relative uptake measurement is often dependent on the software available and is usually made by placing an ROI over each kidney and measuring the integral of the counts in the renal ROI for 1-2, 1-2.5, or 2-3 minutes after injection or using the Rutland-Patlak plot.[8] For the integral method or when patients receive furosemide at the beginning of the study (F = 0), the 1-2 or 1-2.5-minute time periods are preferred[8]; specifically, the measurement should be made before any activity has drained into the ureter or bladder. If the measurement is made after significant activity appears in the ureter or bladder, the relative uptake measurement may be spurious because the rate of initial urine drainage from the two kidneys may not be proportional. A simple visual quality control check can be performed to ensure the measurement interval occurs before the earlier peak of the two renogram curves.

F. Renal size. Routine measurement of renal size at the time of the ^{99m}Tc-MAG3 scan may assist in the detection of unsuspected bilateral increases or decreases in renal size and facilitate scan interpretation as several chronic renal diseases will result in bilaterally small kidneys. Conversely, the kidneys may be bilaterally enlarged in early diabetic renal disease, acute interstitial nephritis, HIV nephropathy, and amyloidosis. Renal size (length in cm and area in cm^2) can be determined from the pixel size and whole-kidney ROI from the ^{99m}Tc-MAG3 renal scan. The mean left and right kidney length (±SD) is 12.2 ± 1.0 cm and 12.1 ± 1.0 cm, respectively, in men and 11.9 ± 0.9 and 11.8 ± 0.9, respectively, in women; the upper and lower limits of renal length and area normalized to body surface area have been previously published.[60]

G. Time to peak. The time to peak refers to the time from radiopharmaceutical injection to the peak height of the renogram. In hydrated subjects, ^{99m}Tc-MAG3 and ^{99m}Tc-DTPA renograms typically peak by 5 minutes after injection and decline to half-peak by 15 minutes.[61] However, physiological retention of the tracer in the renal calyces or pelvis can alter the shape of the whole-kidney renogram in normal kidneys and lead to a prolonged time to peak, 20 minute to maximum count ratio, and half-time (T½) measurement.

H. T½ calculation. The T½ refers to the time it takes for the activity in the kidney to decrease to 50% of its maximum value. The methodology for calculating T½ is not standardized and tends to be vendor- or institution-specific. T½ measurements are affected by the choice of radiopharmaceutical, the interval between administering it and administering furosemide, the method of hydration, the bladder volume, the presence or absence of a bladder catheter, the dose of furosemide, the selection of ROI, the measurement interval, and the algorithm used to fit the washout curve for calculating T½.[5,21,24,57,58]

I. Postvoid kidney to maximum (postvoid/max) count ratio. Simple ratios that incorporate gravity-facilitated drainage from the kidneys, such as counts in the postvoid kidney divided by the maximum counts in the kidney normalized for time, appear to provide more robust measurements of drainage than the T½.[3,43,57] In a study using a dual-acquisition protocol, the mean baseline postvoid/max count ratio for kidneys interpreted as having normal drainage was 0.18 ± 0.16.[57] In the same dual-acquisition study, the ratio of counts at 20 minutes

after furosemide to the maximum counts at baseline was 0.11 ± 0.12 for nonobstructed kidneys.[57]

J. 20 minute to maximum (20 min/max) count ratio. The 20 min/max count ratio is the ratio of the kidney counts at 20 minutes to the maximum (peak) counts normalized for time; this measurement provides an index of transit time and parenchymal function and is often obtained for both whole-kidney and cortical ROIs. For ^{99m}Tc-MAG3, the normal 20 min/max count ratio for cortical ROIs averages 0.19, with SDs of 0.07 and 0.04 for the right and left kidneys, respectively.[62] If the patient is not dehydrated and the 20 min/max count ratio for the cortical ROI exceeds 0.35 (>2-3 SDs above the mean), kidney function is likely to be abnormal. In addition to detecting abnormal function, the 20 min/max count ratio and the 20-min/1-2 min count ratio can be useful in monitoring patients with suspected urinary tract obstruction and renovascular hypertension.[49,50,63,64]

K. Clearance measurements. A measure of renal function can assist in the performance and interpretation of the study, especially as a reduction in renal function may result in delayed tracer uptake and washout even in the absence of obstruction. A reduction in renal function may indicate the need to administer a higher dose of furosemide to achieve an adequate diuretic response. When available, the serum creatinine level provides a global estimate of renal function. A clearance measurement can also be made at the time of the study using plasma- or camera-based clearance measurements. Plasma-based clearances are more accurate than camera-based clearances, but camera-based clearances avoid blood sampling and provide an estimate of global and individual renal function. Plasma- and camera-based clearance measurements have been discussed in more detail in review articles.[18,65-73]

L. Parenchymal transit time. Obstruction of the renal outflow tract has a deleterious effect on nephron function (obstructive nephropathy) that can be detected by a prolonged parenchymal transit time.[74,75] A prolonged parenchymal transit time is not specific to obstruction but increases the likelihood of its presence. The parenchymal transit time calculation is not offered on many commercial systems but can be implemented by following the recommendations in a previously published consensus report.[61]

M. Image display. Static images should be displayed in 1- to 2-minute intervals. The postvoid images should be displayed using the same formatting as the dynamic images to facilitate visual comparison. Images should also be viewed in a cinematic display for optimal interpretation.

X. Interpretation and Pitfalls

Distinguishing between an obstructed and nonobstructed kidney is a particular challenge when the kidney in question has reduced function or a markedly dilated collecting system.[53] A markedly dilated pelvis can serve as a reservoir and, even in the absence of obstruction, can result in slow drainage, a phenomenon sometimes described as the "bathtub effect." Reduced function and a dilated collecting system are common sources of false-positive or indeterminate interpretations. Unfortunately, there is no single measurement that can serve to distinguish between obstructed and nonobstructed kidneys.

All the factors discussed in this procedure standard/guideline can affect the diagnosis of obstruction, with each factor increasing or decreasing the probability of obstruction to a greater or lesser degree. For any particular study, each relevant factor that may affect the interpretation needs to be considered and integrated to reach a conclusion that is consistent with the available data and internally coherent.

The need to consider multiple factors is illustrated by a decision support system to interpret ^{99m}Tc-MAG3 diuretic scans. This system extracts 47 parameters from the renogram, applies a knowledge base of 60 heuristic rules to evaluate the parameters, weighs the parameters and rules with probability factors, and then applies an additional 56 rules to evaluate available clinical information.[76-78] Several of the more important factors in scan interpretation and potential pitfalls are discussed in the following sections.

A. Failure to have the patient void before the study. Drainage from the kidney to the bladder depends on peristalsis and the pressure differential between the renal pelvis and bladder. For patients with impaired peristalsis, the main factor facilitating drainage becomes the pressure differential. A full bladder diminishes the pressure differential and may delay emptying. Moreover, patients who begin the study with a full or partially full bladder may need to void before the study is complete, resulting in a study that is technically unsatisfactory.

B. Dose infiltration. Infiltration of a substantial fraction of the administered activity causes activity to continue entering the bloodstream throughout the acquisition and can lead to a renogram curve, suggesting delayed uptake and delayed washout. The presence of infiltration can be assessed by a short image over the injection site at the conclusion of the study. The degree of infiltration can be estimated by dividing the counts in the area of infiltration by the counts injected.

C. Patient motion. The ROIs are fixed. Patient motion during the study may cause a portion of the kidney or pelvis to be excluded from the ROI, resulting in spurious renogram curves or quantitative indices. When available, motion correction software may be helpful.

D. Errors due to an inconsistent time zero. Data acquisition should begin before bolus injection to avoid missing the initial portion of the study, but the time of starting the computer acquisition is variable. The beginning of the computer acquisition should not be used as time zero for calculation of quantitative indices (see Section VIII.A).

E. T½ derived from whole-kidney vs pelvic ROIs. Drainage has been conventionally assessed by measuring T½ after furosemide administration. Although the method of calculating T½ is not standardized, there is general agreement that prompt clearance of the radiopharmaceutical from the renal collecting system, with a T½ of less than 10 minutes excludes obstruction. For F + 20, F + 30, Fmax, and the furosemide component of dual-acquisition protocols, a T½

calculated from an ROI limited to the counts in a dilated pelvis or collecting system provides a better assessment of the response to furosemide than the T½ calculated from an ROI placed around the whole kidney.[7,24,43,57,58] The advantage of the pelvic ROI is most apparent in poorly functioning kidneys with substantial parenchymal retention.

F. Overreliance on T½. Although a T½ of less than 10 minutes reliably excludes obstruction, a prolonged T½ is not acceptable as an isolated marker for diagnosing obstruction and must be interpreted in the context of the images, curves, and quantitative indices, as well as any clinical or other available imaging information.[3,6,79]

G. Compensating for slower rates of clearance in kidneys with impaired function (output efficiency and normalized residual activity). Kidneys with impaired function often have slower rates of parenchymal uptake and parenchymal clearance than normal kidneys. An important factor slowing down drainage in a kidney with impaired function is a delay in the transport of ^{99m}Tc-MAG3 from the renal tubule to the tubular lumen. The output efficiency index and the normalized residual activity are two measurements to compensate for slower rates of clearance due to reduced renal function. The output efficiency index adjusts the early part of the renogram to the integral of the heart activity curve, whereas normalized residual activity normalizes the activity at any point in the renogram curve to the activity at 1-2 minutes.[80-83] These approaches can assist in the evaluation of drainage, although both measurements are dependent on total renal function, not just the function of a unilaterally impaired kidney.[84] The software for calculating output efficiency index is not available on many commercial systems and a detailed discussion of output efficiency and normalized residual activity are beyond the scope of this procedure standard/guideline.[80-85]

H. Failure to evaluate gravity-assisted drainage. Visual and quantitative measures that incorporate postvoid images into the evaluation of drainage discriminate better than T½ alone between obstructed, equivocal, and nonobstructed kidneys.[3,35,38,57,63,75] Drainage can be quantitated by measuring the residual post-furosemide or postvoid renal counts normalized to the maximum counts.[57,63] As an example, assume the time to peak is 10 minutes and there is still retention in the collecting system after furosemide administration, with a T½ of 18 minutes; the patient voids after the study and the postvoid/max count ratio at 30 minutes is 0.10. This finding indicates that at least 90% of the maximum activity has drained from the kidney in 20 minutes, providing strong evidence against obstruction, whereas basing the interpretation on a T½ of 18 minutes might well have led to an incorrect diagnosis of obstruction. A renal collecting system that empties after micturition is strong evidence against obstruction.

I. Importance of relative renal function. In subjects with normal renal function, the 95% confidence interval for the relative uptake of ^{99m}Tc-MAG3 ranges from 42% to 58% based on the integral method and a perirenal background correction.[62] Patients with a high-grade acute obstruction may demonstrate equal uptake in the two kidneys, but the obstructed kidney may present with an empty pelvis and fail to show any transit of the tracer into the collecting system. High-grade obstruction soon leads to a loss of function in the affected kidney.[1] The likelihood of obstruction is reduced for a patient with suspected unilateral chronic obstruction if the relative renal function is the same in both kidneys, even if quantitative data such as T½ are abnormal. In these cases, it may be appropriate to observe the patient and repeat the study at a later date or to combine the study with sonography to determine whether the size of the renal pelvis is increasing with time.

J. Errors in measurement of relative uptake. In patients with bilaterally impaired function and delayed tracer uptake and excretion, background counts will be high in the first few minutes after injection and will contribute substantially to counts in the kidney ROIs. In this setting, the differential function measurement will be more accurate if the measurement is obtained not during the 1-2, 1-2.5, or 1-3 minutes after injection but rather during the 1 minute just before any tracer leaves the kidney ROIs. At this point, the kidneys will have a higher tracer concentration, the background contribution to counts in the kidney ROIs will be proportionally lower, and the relative renal uptake can be calculated with greater accuracy.[86]

K. Parenchymal transit time and tissue tracer transit. The parenchymal transit time may assist in distinguishing between hydronephrotic kidneys that require intervention to preserve renal function and hydronephrotic kidneys that do not require intervention, but software for making this calculation may not be widely available.[74,75] Tissue tracer transit provides a simple method to assess the parenchymal transit time by visually inspecting the transit of ^{99m}Tc-MAG3 from the renal parenchyma to the renal pelvis.[87,88] A delayed tissue tracer transit is defined visually by a photopenic renal pelvis that is present at the second or third minute after injection, persists through the eighth to tenth minutes, and is accompanied by a stable or increasing parenchymal concentration.[87,88] In a retrospective series, delayed tissue transit times were associated with functional improvement after surgery in 8 of 10 kidneys, whereas normal transit was associated with no loss of renal function.[87]

L. Insufficient dose of furosemide. Patients with chronic renal insufficiency may require higher doses of furosemide to achieve a level in the tubular fluid sufficient to generate an acceptable diuretic response.[54] When overall renal function is normal but one kidney has impaired function, 40 mg of furosemide may not achieve an adequate diuretic response in the impaired kidney even if it is not obstructed. A limited diuretic response may result in delayed washout of the tracer and risk an inappropriate indeterminate or false-positive interpretation. In this setting, a higher dose may be required to compensate for the reduced furosemide secretion and attain an effective level of diuretic in the tubular lumen of the poorly functioning kidney.[52,89]

M. Failure to evaluate diuretic response by measuring voided volume and urine flow rate. Measuring the voided volume and urine flow rate is relatively easy and can alert the nuclear medicine physician to inadequate diuresis. A poor diuretic response may indicate dehydration or impaired renal function and result in a false-positive or indeterminate

interpretation. A patient with normal renal function should produce about 200-300 mL of urine in 20-30 minutes after receiving 40 mg of furosemide.[44] As renal function decreases, the urine flow rate typically decreases, but a urine flow rate of as high as 4 mL/min has been reported for patients with creatinine clearances reduced to 20% of normal,[41,53] and this rate may be sufficient to exclude obstruction in a poorly functioning kidney, particularly if the renal pelvis is not excessively dilated.

As renal function further deteriorates, an abnormal diuretic response cannot reliably distinguish obstruction from a poorly functioning kidney that failed to respond to furosemide. Conversely, if the kidney has a normal or near-normal clearance, it should have a good diuretic response, and collecting system retention after furosemide is much more suggestive of obstruction.

N. False-positive interpretations in patients receiving diclofenac. Diclofenac, a nonsteroidal anti-inflammatory drug that blocks the production of prostaglandins, has been shown to inhibit spontaneous ureteric contraction, prolong transit time, and delay the time to peak height of the renogram curve for ^{99m}Tc-MAG3 in healthy individuals.[90-92] Ideally, this drug should be discontinued before the scan to minimize the possibility of an indeterminate or false-positive result. The possibility that other nonsteroidal anti-inflammatory drugs might have a similar effect has not been investigated. If abnormal drainage suggesting obstruction occurs in a patient receiving diclofenac, consideration should be given to repeating the study after diclofenac has been discontinued.

O. Failure to use a urinary drainage catheter for patients with a urinary diversion or noncompliant bladder. Patients with a urinary diversion or noncompliant bladder may require catheterization to optimally evaluate drainage from the renal collecting system. Patients with a neobladder are at an increased risk of reflux, making the evaluation of washout more problematic. When feasible, the neobladder or ileal diversion should be catheterized before the study to empty any residual urine, and the catheter should be left in place during the study to allow drainage and minimize the possibility of reflux.[93]

P. Use of inappropriate reference standards. Use of inappropriate reference standards can lead to errors in interpretation such as using *parenchymal* ROI normal values as the reference standard for *whole-kidney ROI* measurements of the T½ or 20 min/max count ratio.[62]

Q. Mistaking gallbladder for kidney. A small fraction of the administered dose of ^{99m}Tc MAG3 is transported to the gut via the hepatobiliary system; this fraction increases in patients with impaired renal function.[94] Occasionally, activity in the gallbladder has been mistaken for renal activity, and delayed images may show bowel accumulation.[94-97]

XI. Special Cases

A. Acute renal colic. Unenhanced helical CT has rapidly gained acceptance as the procedure of choice for patients presenting with acute renal colic. Unenhanced helical CT avoids the risk of contrast material, which is particularly important for patients with renal insufficiency, diabetes, dehydration, or allergy to iodinated contrast agents. Moreover, stone size can be accurately ascertained, and the correct diagnosis can be made in approximately 50% of patients whose symptoms are not caused by a renal stone.

Knowledge of the size of the obstructing calculus is important because calculi smaller than 5 mm generally pass spontaneously; as the size of the calculus increases, spontaneous passage becomes less likely. Many calculi between 3 and 8 mm in size are followed up conservatively in the hope of spontaneous passage, and patients may be managed on an outpatient basis. Despite its advantages, unenhanced helical CT cannot determine the functional status of the kidney. Larger stones (5-8 mm) may not be associated with high-grade obstruction and can be managed conservatively, whereas some small stones (3-5 mm) do result in high-grade obstruction and may need more aggressive management. Obtaining a diuretic renal scan to determine the presence or absence of obstruction while the patient is in the emergency room has been shown to direct patient management.[39,40,98,99] One study found that the scan changed the decision to admit or discharge the patient in 30% of cases.[99]

B. Transplants. This procedure standard/guideline applies to renal transplant patients with suspected obstruction analogous to that in a patient with a single native kidney. In transplanted kidneys, however, ureteral peristalsis is often reduced, probably due to ureteral denervation. Therefore, it is not uncommon to observe a persistent visualization of the whole ureter, without any obstruction and in the absence of acute rejection. When acute rejection occurs, it must be remembered that the ureter is part of the graft and may lose peristalsis to produce a pseudo-obstruction.[100]

XII. Documentation or Reporting

Using a specified, organized structure for documentation may fundamentally alter the way interpreting physicians think about the case as they produce the report.[101] For certain procedures such as diuresis renography, structured documentation of data requires structured acquisition of data. The structure specifies what elements should be acquired to ensure a study of maximum diagnostic utility. Adopting a structured format for documentation and acquisition will guide the assembly of elements essential to reaching an informed conclusion, allowing physicians to ensure the quality of diuresis renography studies performed in their departments. The use of a consistent format has the additional advantage of easy retrieval of data, which can be broadly analyzed to support medical research and quality improvement. Finally, the structured format allows outside observers to assess quality; the essential elements are either present or absent. A more detailed discussion of structured reporting in diuresis renography, including the recommended elements and rationale, is available in a 2012 consensus report,[3] and a sample structured report template is included as Appendix. The following information should be included in the report.

A. History. The history should specify the clinical indication; patient demographics; most recent creatinine level, including date of measurement; current diuretic medications; relevant urologic procedures and surgeries; and relevant results from prior imaging procedures.

B. Procedure. The method (oral or intravenous) and volume of hydration administered in the department should be recorded, or the report should state that no additional hydration was provided. If a nephrostomy tube is present, the report should state whether the tube was clamped or unclamped during the study. The presence of a bladder or urinary diversion catheter should be reported. The imaging procedure should be described (one- or two-stage acquisition). The dose and timing of furosemide should be clearly documented, and if a baseline study excludes renal obstruction, the report should state that furosemide was not administered. The ROIs used (whole-kidney, parenchymal, pelvic) and background subtraction method should be stated, as well as the quantitative measurements generated. If clearance was measured, the method should be stated. The patient position (supine, sitting, erect) should be specified.

A statement that an image of the injection site was obtained identifies that an important quality control step was performed and should be considered for inclusion in the report. If residual urine volume was measured, the voided volume and method of calculation should be briefly described.

C. Findings. The findings should include a comment on the quality of the study and describe any problems. The relative uptake of the two kidneys should be reported and rounded to the nearest whole percent, as measurement to the tenth of a percent is not accurate (eg, 42%, not 41.7%). The size, shape, and position of the kidneys should be described. A qualitative description of tracer uptake and washout should be included. Quantitative measures used to assess drainage and function should be reported, including reference values when appropriate. If calculated, the residual urine volume should be stated. Finally, the presence and location of diuretic-induced flank pain should be noted as this finding may be associated with an increased likelihood of obstruction.

D. Impression. The impression section of the report should answer the clinical question. This section should clearly state whether obstruction is present or absent, or it should state that the study is indeterminate. If uncertainty exists in the interpretation, a confidence level may be included, but the results should not be unnecessarily qualified.

Avoid the term *partial obstruction*. This term is ambiguous, has no generally accepted meaning, and should not be used as an expression of uncertainty. In response to an impression of partial obstruction, a surgeon has been said to have replied, "Does that mean I should perform a partial nephrostomy with a partial knife?"

As a rationale for the diagnosis, summarize the major factors contributing to the final interpretation. Also, summarize important results that may affect patient management, such as relative function, a large postvoid residual, reduced ^{99m}Tc-MAG3 clearance, or comparison with a prior study.

XIII. Equipment Specification

Gamma camera quality control will vary from camera to camera. For further guidance on routine quality control procedures for gamma cameras, refer to the SNMMI Procedure Standard for General Imaging and the EANM guideline on routine quality control for nuclear medicine instrumentation.[102]

XIV. Quality Control and Improvement

Besides the quality control issues and potential pitfalls discussed in this paper, this topic will be further addressed in an upcoming SNMMI procedure standard/EANM practice guideline for renal scintigraphy in adults. Although the SNMMI website (snmmi.org) does not currently list any quality improvement projects focusing on diuretic renography, the online education programs on the website include templates for quality improvement projects to aid in documenting a maintenance-of-certification part IV project.

XV. Safety, Infection Control, and Patient Education Concerns

See the SNMMI Procedure Standard for General Imaging.

XVI. Radiation Safety in Imaging

After intravenous injection of ^{99m}Tc-MAG3, the effective dose for an adult with normal renal function is 0.007 mSv/MBq.[103] This calculation assumes that the patient does not void until 3.5 hours after tracer administration, and that the bladder wall contributes 80% to the effective dose. If the patient voids 30 minutes after tracer administration, the effective dose is reduced from 0.007 to 0.0017 mSv/MBq.[103] Several factors affect the radiation dose to the bladder, and a single voiding at 30 minutes may not always minimize radiation exposure if subsequent voiding is delayed by several hours.[104] The EANM Dosimetry Committee has a guidance document on dosimetry reporting.[105] In addition, an SNMMI/EANM procedure standard/guideline on dosimetry is being developed; when approved and available, this "new document" will supersede the radiation dosimetry estimates in individual standard and guideline.

In summary, the critical organ is the bladder wall, and the radiation dose to the bladder wall can be substantially reduced by instructing the patient to void at the conclusion of the study, maintain hydration, and continue to void at 30- to 60-minute intervals for 3 hours after the study. This approach will minimize exposure to radiation regardless of the level of renal function, administration of furosemide, or presence of an obstructed kidney.[30,103,106]

XVII. Issues Requiring Additional Study

A. Acute obstruction. The role of diuretic renography in the setting of acute obstruction needs further study. Pilot studies

have shown that diuretic renal scintigraphy in the emergency room can have a substantial impact on the management of patients presenting with renal colic and a ureteral calculus documented by unenhanced CT.[39,40,98,99] Additional studies are needed to confirm these initial results and evaluate both the cost-effectiveness and the impact of diuretic renography on patient management and outcome.

B. Tissue tracer transit, output efficiency, normalized residual activity, and postvoid to maximum count ratios. Preliminary studies suggest that tissue tracer transit can help differentiate between kidneys at risk of losing function and those not at risk.[87,88] The output efficiency index and the simpler approaches of normalized residual activity and residual post-furosemide or postvoid renal counts normalized to maximum counts have also been proposed to reduce the number of false-positive or indeterminate diuretic renograms.[57,80,107] Additional studies need to be performed on adults to confirm and further evaluate the utility of these measurements.

C. Dose of furosemide for patients with unilaterally impaired renal function. Earlier in this paper, we described the rationale for increasing the dose of furosemide to obtain adequate diuresis in patients with a reduced ^{99m}Tc-MAG3 clearance or an elevated serum creatinine. A patient with one normal kidney will have a normal serum creatinine, but the standard 40-mg dose of furosemide may not be sufficient to generate adequate diuresis in the poorly functioning contralateral kidney. The possibility that higher levels of furosemide may be required to appropriately evaluate the poorly functioning kidney needs additional investigation.

D. Decision support systems. Decision support systems have had an increasing impact on the practice of medicine and are rapidly being extended to the analysis and interpretation of images. RENEX and iRENEX are renal expert systems designed to assist physicians in the interpretation of diuretic ^{99m}Tc-MAG3 renography studies performed for suspected renal obstruction.[76,108] Initial data suggest that the interpretations of RENEX (automated analysis of the quantitative data derived from renogram acquisition) are indistinguishable from the interpretations of expert readers[76,108]; moreover, pilot studies of iRENEX (RENEX plus clinical information) have shown that it performs comparably to experts with clinical information, can reduce interobserver variability among resident physician interpretations, and can lead to better agreement between resident and expert interpretations.[109,110] Although these decision support systems are promising, they are still under investigation and need broader development and evaluation.

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Approval

This standard/guideline was approved by the Board of Directors of the SNMMI on January 30, 2018 and by the EANM Board on September 1, 2017.

Appendix Sample Structured Report Template (3)

Indication

The patient is a ___ -y-old [male/female] referred for [list referral reason].

Clinical history

There are no reports of a recent serum creatinine test, urologic procedure, or renal imaging study. [The most recent available serum creatinine level, dated ___, is ___.]

Procedure

The patient [did/did not] receive additional hydration [which consisted of ___]. The patient voided before

the procedure, the voiding time was recorded, and the patient received an intravenous injection of ___ [mCi/MBq] of [^{99m}Tc-MAG3/ethylenedicysteine], resulting in a radiation dose approximately ___% of the 3-mSv yearly background radiation. [Describe imaging protocol, number of stages, and dose and timing of furosemide, if administered]. The [^{99m}Tc-MAG3/ethylenedicysteine] clearance was calculated using [a camera-based, single-blood-sample, multiple-blood-sample] technique. Data were analyzed using a dedicated computer. ROIs were assigned over each kidney and the renal cortex; a ___ background region was assigned and the relative uptake was calculated at [time interval and calculation method]. The following quantitative parameters were calculated: ___. The patient voided at the conclusion of the study; the voided volume was measured, and the time of voiding was recorded to determine the urine flow rate. Pre- and postvoid bladder images were obtained to calculate residual urine volume, and a postvoid image of the kidney was obtained to evaluate gravity-assisted drainage.

Findings

The study is of good quality. [If obtained] The [^{99m}Tc-MAG3/ethylenedicysteine] clearance is ___ mL/min/1.73 m^2, compared with a normal range of ___ to ___ mL/min/1.73 m^2. The relative uptake of the left and right kidneys is ___% and ___%, respectively. The kidneys have a normal configuration, comparable size, and no abnormal areas of decreased tracer activity. There is prompt uptake of the tracer in both kidneys, with rapid excretion after furosemide; there is no significant retention in either collecting system. [Provide the relevant quantitative results that form the basis for the interpretation.] The voided volume was ___ mL, the residual urine volume was ___ mL, and the urine flow rate was ___ mL/min.

Impression

1. The relative uptake is ___ in the left kidney is and ___ in the right kidney.
2. (If performed) The [^{99m}Tc-MAG3/ethylenedicysteine] clearance is ___ mL/min/1.73 m^2, with a reference range of ___ to ___ mL/min/1.73 m^2.
3. (If performed) The residual volume is ___ mL.
4. Neither kidney is obstructed. There is prompt uptake of the tracer in both kidneys and rapid drainage from both collecting systems after furosemide administration.

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