



## The SNMMI and EANM practice guideline for renal scintigraphy in adults

M. Donald Blaufox<sup>1</sup> · Diego De Palma<sup>2</sup>  · Andrew Taylor<sup>3</sup> · Zsolt Szabo<sup>4</sup> · Alain Prigent<sup>5</sup> · Martin Samal<sup>6</sup> · Yi Li<sup>7</sup> · Andrea Santos<sup>8</sup> · Giorgio Testanera<sup>9</sup> · Mark Tulchinsky<sup>10</sup>

Received: 4 August 2018 / Accepted: 8 August 2018 / Published online: 30 August 2018  
© Springer-Verlag GmbH Germany, part of Springer Nature 2018

### Abstract

**Purpose** 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. 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. SNMMI and EANM members are physicians, technologists, and scientists specializing in the research and practice of nuclear medicine.

**Methods** The SNMMI and EANM will periodically define new guidelines for nuclear medicine practice to help advance the science of nuclear medicine and to improve the quality of service to patients throughout the world. Existing practice guidelines will be reviewed for revision or renewal, as appropriate, on their fifth anniversary, or sooner, if indicated.

---

**Preamble** The Society of Nuclear Medicine and Molecular Imaging (SNMMI) and the European Association of Nuclear Medicine (EANM) have written and approved guidelines to promote the use of nuclear medicine procedures with high quality. These 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 and EANM caution against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by medical professionals taking into account the unique circumstances of each case. Thus, an approach that differs from the guidelines does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of the guidelines.

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 at times to identify the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to these guidelines will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these guidelines is to assist practitioners in achieving this objective.

---

✉ Diego De Palma  
didepal@tin.it

**Conclusion** Each practice 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 and EANM recognize that the safe and effective use of diagnostic nuclear medicine imaging requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published practice guideline by entities not providing these services is not authorized.

**Keywords** Renal dynamic scan · Renal static scan · Adults · EANM · SNMMI · Guideline

## Introduction

Renal scans are safe and widely available tests that provide information about the morphology and function of the kidneys utilizing radiopharmaceuticals with high renal clearance [1]. This information supplements that obtained by other imaging methods (Ultrasound, CT, MRI) [2, 3], and its special value is to measure relative renal function. Anatomical abnormalities causing renal vascular or urinary tract malfunction can be clarified. This potential can be enhanced with drugs that stress renal functional capability. Radiopharmaceuticals used to perform renal scans can be divided into three major categories: filtered by the glomerulus, secreted by the tubules, and retained in the tubules via receptor-mediated endocytosis.

Functional agents (filtered by the glomerulus and/or secreted by the tubules) are used in the dynamic renal scan (renography), and morphological agents (retained in the tubules) are used in the static (cortical) renal scan.

Dynamic scans elucidate the uptake and drainage of the radiopharmaceutical, and allow the generation of time-activity curves by selection of regions of interest, while static

scans image the functional renal tissue and provide useful morphologic information.

An understanding of the principles of the test, its limitations, and the sources of error is essential to the interpretation of the results and effective use of renal scintigraphy.

## Goals

The purpose of this guideline is to provide practitioners with a summary of radiopharmaceuticals, techniques, and clinical indications for performing renal scintigraphy in adults. This overview will not deal with radiopharmaceuticals or indications currently under investigation or used for clinical trials or research. Any and all of these guidelines are only advised where the needed technology and radiopharmaceuticals are available and licensed.

## Definitions

Not applicable.

## Common clinical indications

Major indications [4] for renal scintigraphy include, but are not limited to, the following:

- a) Acute and chronic renal failure
- b) Unilateral/bilateral renal disease (space-occupying lesions included)
- c) Obstructive uropathy
- d) Renovascular hypertension
- e) Status post renal transplantation
- f) Pyelonephritis and parenchymal scarring

Optimal assessment of the existence of obstructive uropathy usually requires diuretic renography [5–8], i.e., the use of a diuretic drug, such as furosemide, to initiate a maximal diuresis. This test has become one of most common procedures in daily renal nuclear medicine practice and is very useful in differentiation of obstructive or non-obstructive

---

M. Donald Blaufox  
mdonald.blaufox@einstein.yu.edu

Andrew Taylor  
andrew30350taylor@gmail.com

Zsolt Szabo  
zszabo@jhmi.edu

Alain Prigent  
prigentlaine@yahoo.fr

Martin Samal  
samal@cesnet.cz

Yi Li  
yilimd@gmail.com

Andrea Santos  
andrea.fa.santos@gmail.com

Giorgio Testanera  
arcivampiro@gmail.com

Mark Tulchinsky  
mark.tulchinsky@gmail.com

Extended author information available on the last page of the article

causes of a dilated renal pelvis [9]. This test is the subject of a separate guideline devoted to obstructive uropathy.

In the case of suspected renovascular hypertension, it is recommended to perform an angiotensin-converting enzyme (ACE) inhibition (ACEI) renogram. In the era of CT angiography, MR angiography, and Doppler vascular sonography, the role of ACEI renography has diminished [10–12]. It is also the subject of a separate guideline.

In renal transplant recipients, a major field of focus is the differential diagnosis between rejection and acute tubular necrosis (ATN), the latter characterized by images showing relatively preserved renal perfusion in comparison to function [13–15]. A comprehensive review was published by Dubovsky et al. [16]

Urinary tract infections (UTIs) often are clinically divided into febrile or non-febrile.  $^{99m}\text{Tc}$ -dimercaptosuccinic acid (DMSA) is the best imaging agent to visualize renal parenchymal involvement, to help distinguish pyelonephritis from lower urinary tract infections in febrile patients. Renal cortical scintigraphy also is used to evaluate kidney scarring after pyelonephritis. It can be employed reliably no less than 6 months after the last febrile UTI. [17]

## Qualifications and responsibilities of personnel

In the USA, see Section V of the SNMMI Guideline for General Imaging. In Europe, the certified nuclear medicine physicians who perform the study and sign the report are responsible for the procedure, complying with national laws and rules.

## Procedure/specifications of the examinations

### Request

The request for the study should include all relevant clinical, laboratory, and imaging information. The nuclear medicine physician should be aware of relevant urologic procedures and surgeries such as the site of the renal graft, the presence of a nephrostomy tube, ureteral stent, or urinary diversion. The supervising/interpreting nuclear medicine physician should review all available clinical, laboratory, and radiological data prior to performing the study.

### Patient preparation and precautions

Renal radionuclide scans generally require no specific preparation: patients can avoid fasting, and should be in good state of hydration. Pregnancy is a contraindication to radiopharmaceutical administration for imaging, but not for glomerular filtration rate (GFR) determination using 51-Cr-ethylenediamine tetraacetic acid (EDTA) if needed [see

International Commission on Radiological Protection (ICRP)]. Adverse reactions to renal radiopharmaceuticals are quite rare: no major reaction has ever been reported.

## Radiopharmaceuticals

When performing dynamic renal studies, the radiopharmaceuticals can be divided into two categories:

1. High-extraction renal plasma flow (ERPF) agents (tubular extraction) including 131-I-hippuran, 123-I-hippuran,  $^{99m}\text{Tc}$ -MAG3 (mercaptoacetyl-triglycine), and  $^{99m}\text{Tc}$ -EC (ethylenecysteine).
2. Glomerular filtration agents, including  $^{99m}\text{Tc}$ -DTPA (diethylenetriamine pentaacetic acid) and 51-Cr EDTA

Radiopharmaceuticals for static scintigraphy are  $^{99m}\text{Tc}$ -DMSA and  $^{99m}\text{Tc}$ -glucoheptonate (GH); both accumulate primarily in the renal cortex and fall into a third category.

131/123-I-Orthiodohippuran (OIH), a classic renal tubular agent that has been used as a substitute for para-aminohippurate (PAH), was introduced by Tubis [18]. The 131-I label, once used for probe renography, yields very low-quality images with a high radiation dose and is no longer used.

$^{99m}\text{Tc}$ -MAG3 [19], is similar to OIH [20], although it has very little glomerular filtration due to its high plasma protein binding, resulting in a lower extraction fraction [21].  $^{99m}\text{Tc}$ -MAG3 is currently the most frequently used renal tubular agent in nuclear medicine practice. Since its excretion is directly related to proximal tubular function (i.e., 60% of PAH on average), Bubeck et al. proposed the concept of tubular extraction rate (TER) [22] to replace the term ERPF.

$^{99m}\text{Tc}$ -DTPA is excreted by glomerular filtration without renal tubular secretion. The renal clearance is slightly lower than inulin, and it was first used clinically in 1970 [23]. There is about 5–10% protein-bound DTPA in the plasma after 1 h. DTPA labelled with  $^{99m}\text{Tc}$  remains the most suitable radiopharmaceutical for combined measurement of GFR and renal imaging clinically.

51-Cr-EDTA is used commonly in Europe to measure GFR [24, 25]. It is not licensed in the US and is not suitable for imaging.

$^{99m}\text{Tc}$ -DMSA [26] and  $^{99m}\text{Tc}$ -GH [27] were proposed in early 1970s. They are mainly bound in the proximal tubule in the renal cortex for a prolonged time after injection and are suitable for static renal imaging to detect a renal mass or defects in the renal parenchyma. These agents are also called renal cortical agents.  $^{99m}\text{Tc}$ -DMSA is commonly used because of its higher retention in the renal parenchyma (30% vs 5–10% of GH) [28]. These numbers are approximations, and there is some evidence of secretion of DMSA by the distal tubule [29]. Because of its high retention in the kidney, the

radiation dose of DMSA is significant and the administered dose should be chosen with that in mind.

## Protocol/image acquisition

### Renal dynamic scintigraphy

Renal dynamic scintigraphy (radionuclide renography or nephrogram) consists of serial imaging after intravenous administration of the selected radiopharmaceutical, to investigate perfusion, functional uptake, cortical transit, and excretion. It is recommended also to obtain a later static image after standing upright and voiding. These all take place in a single imaging session.

- Patient preparation: good hydration before and after radiopharmaceutical administration is essential. The patient should void before the beginning of the scan.
- <sup>99m</sup>Tc-labeled radiopharmaceuticals (adults): from 90 to 200 MBq. The higher activity is suggested for studying renal perfusion, when indicated. It is strongly recommended to optimize protocols according to the ALARA principles.
- Radiation burden: less than 1 mSv with the activities below 100 MBq [30, 31]. Specific information is detailed in Tables 1 and 2.
- Radiopharmaceutical administration: intravenous bolus injection, carefully avoiding extravasation; a butterfly needle or intravenous catheter is recommended when performing a furosemide (diuretic) or ACEI renogram (captopril).
- Timing after injection and scan framing: a commonly used technique involves dynamic acquisition of 1–2-s

**Table 2** Dose to the fetus per unit activity administered to the mother (mGy/MBq)

	Early	3 months	6 months	9 months
<sup>51</sup> Cr EDTA*	$3.4 \times 10^{-3}$	$2.6 \times 10^{-3}$	$1.3 \times 10^{-3}$	$1.2 \times 10^{-3}$
<sup>123</sup> I Hippuran†	$3.1 \times 10^{-2}$	$2.4 \times 10^{-2}$	$8.4 \times 10^{-3}$	$7.9 \times 10^{-3}$
<sup>131</sup> I Hippuran**	$9.8 \times 10^{-2}$	$6.8 \times 10^{-2}$	$2.0 \times 10^{-2}$	$1.4 \times 10^{-2}$
<sup>99m</sup> Tc DMSA**	$5.9 \times 10^{-3}$	$8.8 \times 10^{-3}$	$3.4 \times 10^{-3}$	$2.2 \times 10^{-3}$
<sup>99m</sup> Tc DTPA**	$1.7 \times 10^{-2}$	$1.1 \times 10^{-2}$	$3.8 \times 10^{-3}$	$3.2 \times 10^{-3}$
<sup>99m</sup> Tc EC*	$1.3 \times 10^{-2}$	$9.7 \times 10^{-3}$	$4.0 \times 10^{-3}$	$3.8 \times 10^{-3}$
<sup>99m</sup> Tc glucoheptonate**	$1.6 \times 10^{-2}$	$1.4 \times 10^{-2}$	$4.8 \times 10^{-3}$	$3.7 \times 10^{-3}$
<sup>99m</sup> Tc MAG3**	$2.6 \times 10^{-2}$	$1.8 \times 10^{-2}$	$5.7 \times 10^{-3}$	$4.1 \times 10^{-3}$

\* No published data. Personal communication, M Stabin, 2017

† Russell JR and Stabin MG, Sparks RB and Watson EE. Radiation Absorbed Dose to the Embryo/Fetus from Radiopharmaceuticals. Health Phys 1997; 73 [5]:756–769

\*\*Stabin MG. New Generation Fetal Dose Estimates for Radiopharmaceuticals. JNM 2018, in press

images for 1–2 min (“vascular” phase), starting immediately after radiopharmaceutical administration. It is followed by 10–15-s images for about 5 min (functional uptake cortical transit), and then 20–30-s images for about 20 min (excretion phases), with a total scan time of 20–30 min. All of the functions actually occur concurrently, but these are the times when one or the other dominates. A post-micturition post-erect image for the same duration as the last frame of the renogram is frequently indicated clinically.

- Patient positioning: supine position; be careful to reduce motion. In patients who cannot lie flat, it is possible to

**Table 1** Radiation dosimetry in adults

Radiopharmaceutical	Administered activities				Largest radiation dose			Effective dose	
	MBq min	MBq max	mCi min	mCi max	Organ	mGy/MBq	rad/mCi	mSv/MBq	rem/mCi
<sup>51</sup> Cr EDTA**	3.7	–3.7	0.1	–0.1	Bladder	0.024	0.0895	0.0020	0.008
<sup>123</sup> I Hippuran†	3.7	–14.8	0.1	–0.4	Bladder	0.19	0.71	0.0120	0.045
<sup>131</sup> I Hippuran†	1.295	–1.295	0.035	–0.035	Bladder	0.92	3.43	0.0520	0.196
<sup>99m</sup> Tc DMSA*	74	–222	2.0	–6.0	Kidney	0.20	0.72	0.0072	0.027
<sup>99m</sup> Tc DTPA*	185	–370	5.0	–10.0	Bladder	0.069	0.26	0.0046	0.017
<sup>99m</sup> Tc EC**	185	–370	5.0	–10.0	Bladder	0.057	0.21	0.0092	0.034
<sup>99m</sup> Tc glucoheptonate#	370	–555	10.0	–15.0	Bladder	0.056	0.21	0.0090	0.034
<sup>99m</sup> Tc MAG3*	185	–370	5.0	–10.0	Bladder	0.12	0.44	0.0064	0.024

\*Data are from Stabin MG, Siegel JA. RADAR Report: A Compendium of Radiopharmaceutical Dose Estimates Based on OLINDA/EXM Version 2.0. J Nucl Med 2018 59:154–160

\*\* Data are from (ICRP Publication 128. Radiation Dose to Patients from Radiopharmaceuticals - A Compendium of Current Information Related to Frequently Used Substances, ICRP Publication 128, Ann ICRP 44(2S), 2015)

† Data are from (ICRP Publication 80. Radiation Dose to Patients from Radiopharmaceuticals (Addendum to ICRP Publication 53) Ann. ICRP 28 [3], 1998)

# Data are from (Radiation Dose to Patients from Radiopharmaceuticals ICRP Publication 53 Ann. ICRP 18 [1–4], 1988)

perform the exam seated with the back on a gamma camera detector.

- g. Technical parameters: dynamic image acquisition
- h. Collimator: low-energy/high-resolution (LEHR) or general purpose, according to availability
- i. Minimum matrix:  $64 \times 64$  or  $128 \times 128$  pixel
- j. Views: posterior. Anterior views must be acquired in the presence of horseshoe or ectopic kidney or kidney transplant. Lateral views may be obtained at the end of the renography if renal depth measurements are needed.
- k. After imaging: patient should be advised to maintain hydration and frequent bladder emptying during the rest of the day.
- l. ACEI renography: radiopharmaceutical is administered approximately 1 h after oral administration of 25 to 50 mg of captopril or 10 to 20 min after intravenous injection of 40 micrograms/kg (maximum 2.5 mg) of enalaprilat. Blood pressure should be measured before administration of the ACEI and monitored every 10 to 15 min. An intravenous line should be kept in place for the IV test to allow prompt fluid replacement if the patient becomes hypotensive. One protocol is to obtain a baseline scan without an ACEI followed by a repeat examination after administration of an ACEI on the same or following day. The combined examinations help to detect significant ACE-induced scintigraphic abnormalities [32, 33]. An alternative protocol is to obtain the examination with an ACEI first. 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 ACE inhibitor is abnormal, a baseline examination is needed the next day or later. Chronic use of an ACEI may decrease the sensitivity of the test. An ACEI should be discontinued for 3 to 7 days before the test. If stopping the drugs is not possible, the study may still be performed, [32] but the sensitivity is decreased. See the SNMMI guideline on this subject.

### Static renal scan (renal cortical scintigraphy)

- a. Radiopharmaceutical:  $^{99m}\text{Tc}$ -DMSA provides the best images. GH may also be used.
- b. Adult activity: 111 MBq
- c. Radiation burden: approximately 1 mSv [30]
- d. Patient preparation: good hydration before and after radiopharmaceutical administration
- e. Radiopharmaceutical administration: intravenous injection carefully avoiding extravasation
- f. Timing after injection: Image acquisition should start from 2 to 4 h after radiopharmaceutical administration.

In the presence of poor renal function, late images (up to 20 h) are helpful.

- g. Patient positioning: supine position; be careful with patient comfort to reduce motion.
- h. Technical parameters: static image acquisition
- i. Collimator: LEHR, Low-energy/ultra-high-resolution (LEUHR), or pinhole collimator
- j. Minimum matrix:  $128 \times 128$  or  $256 \times 256$  pixel with magnification (zoom) set to yield a preferred pixel size of 2–4 mm.
- k. Total counts/time per view: At least 200,000 total counts must be acquired or use a fixed time of 5–10 min/per view. If a pinhole collimator is being used, 100,000 to 150,000 total counts or 10 min should be acquired per view.
- l. Views: posterior and  $30^\circ$ – $35^\circ$  posterior oblique views. The anterior view must be considered if there are abnormalities of number, shape, and position of the kidneys. Single-photon emission computed tomography (SPECT) images can be acquired, but there is no consensus on its usefulness [34].
- m. After imaging: Patient should be advised to maintain hydration and frequent bladder emptying during the rest of the day to minimize radiation dose to the kidneys and bladder.

## Processing

### Split (relative, differential) renal function

Accuracy and reproducibility of the measurement of split renal function (SRF) depends on kidney size and kidney function and strict attention to technique. Smaller kidneys and those with reduced function are associated with lower accuracy and precision of the measurement of split renal function. Other factors affecting accuracy are intrarenal vascular and extra-renal (extravascular and vascular) background, attenuation, and scatter. Main sources of error in the measurement of split renal function are background activity and attenuation [35–38].

The measurement of SRF with dynamic renal scintigraphy requires drawing a region of interest (ROI) around each kidney and the generation of curves (renograms) from each ROI after the subtraction of area-normalized background ROIs. The most accurate background ROIs are C-shaped surrounding the lower, lateral, and upper part of the kidney. The SRF is then calculated with a mathematical algorithm applied to the uptake part of the curve.

The recommended time periods are 90–150 s for  $^{99m}\text{Tc}$ -MAG3 or EC, and 120–180 s for  $^{99m}\text{Tc}$ -DTPA.

There are two generally accepted models of equivalent accuracy; the slope method with the Patlak-Rutland [39] plot and the integral method. [40] A recent report suggests a method developed by Wesolowski using liver activity to help with the normalization, but it has not yet been confirmed fully [41].

The measurement of SRF with static renal scintigraphy requires drawing a ROI around each kidney to calculate the percent contribution of each kidney counts to the total counts, too. The subtraction of area-normalized background ROIs is not strictly necessary in patients with good renal function, but it is mandatory in case of poor renal function [34]. Unfortunately, in the case of poor renal function, the errors of the measurement increase [42].

Attenuation correction usually is not necessary if the distance of the left and right kidneys from the detector is approximately the same so that both kidney counts are attenuated to the same extent [43]. It is necessary to correct for attenuation in patients with ectopic or displaced kidneys. The method of choice is to measure split renal function using the geometric mean image calculated from combined posterior and anterior views; for dynamic studies, this is feasible using a dual-head gamma camera for the scan [44].

### Total (absolute) renal function

Total renal function (GFR and ERPF) assessment may be performed using radionuclides. This is a non-invasive and reproducible methodology [45]. Several methods have been introduced for this purpose [22, 46–51].

A comprehensive analysis is beyond the purposes of this guideline.

### Interpretation

Interpretation of the scan is highly dependent on the radiopharmaceutical used for imaging. The most frequently used compounds at present are  $^{99m}\text{Tc}$ -MAG3 and  $^{99m}\text{Tc}$ -DTPA. The latter can be used for the same indications, but the images are not as good because of greater background interference. This disadvantage is offset to some degree by the lower associated radiation dose.  $^{99m}\text{Tc}$ -DTPA provides a better assessment of renal perfusion and, when administered in a higher dose, helps evaluate vascular compromise and to differentiate ATN from acute transplant rejection. Relatively preserved perfusion with reduced function is also seen in acute contrast nephropathy.

$^{99m}\text{Tc}$ -MAG3 is preferred over  $^{99m}\text{Tc}$ -DTPA for functional imaging of the kidneys because of its rapid accumulation in the kidney tubules. Although it is less suited to differentiate preserved perfusion in ATN (tubular retention is associated with a higher dose), it is more effective in detecting renal outflow obstruction, increased parenchymal transit, renal transplant dysfunction, renal trauma, and post-traumatic or iatrogenic urinary leaks.

Nephrotoxic drugs can prolong parenchymal radiotracer transit and, depending on the severity of damage, can also cause reduced parenchymal uptake. Progress in the development of in vitro methods to detect rejection has led to decreased use of this test.

Space-occupying lesions can be detected by functional imaging as parenchymal defects. However, ultrasound, CT, and MR imaging are best suited for evaluation of renal masses and should be recommended when regional defects in the parenchyma are detected. Functional imaging may play a role before surgical interventions to predict expected residual renal function after partial or complete unilateral nephrectomy.

Infectious/inflammatory diseases may result in reduced parenchymal function. Renal cortical defects may be seen in focal pyelonephritis, renal abscess, and with post pyelonephritic scarring.

While in the past, radionuclide imaging was used extensively for differentiation of ATN from acute rejection, today it is mostly used for diagnosis of surgical complications such as urinary leakage, renal artery stenosis, or obstruction. While CT, US, or MRI provide exquisite details of the anatomical changes, scintigraphy can help assess regional kidney function and rule out urine leakage. SPECT/CT at the end of a functional study will localize a urinoma.

False positive findings can be due to pseudo-tumors of the kidneys (non-malignant masses that can mimic renal tumors). Developmental abnormalities with normal parenchymal function include persistent fetal lobulation, dromedary hump, or prominent columns of Bertin.

### Special considerations for children

See Pediatric guidelines.

### Documentation and reporting

The report should contain the essential elements required to evaluate and interpret the study and aims to communicate the results to the referring physician in a clear and concise manner designed to optimize patient care. Information not included into the report should be available for retrieval from a digital or paper archive.

#### I) Study identification

- a. Patient name and surname, and medical record number or patient code, if appropriate
- b. Age or date of birth and gender
- c. Date of study (and time of different acquisitions if relevant)

- d. Type of renal test such as radionuclide renography (and either diuresis renography or captopril renography if applicable), renal cortical scintigraphy (renal cortical SPECT) or evaluation of renal allograft
- e. Administered radiopharmaceutical and activity, estimation of the effective dose as expressed in mSv

## II) Clinical information

### a. Indication:

The reason for referral is the justification for performing the study and should indicate the clinical question the study is designed to answer.

### b. Other relevant history.

b-1. State the most recent serum creatinine values and date. Otherwise, state there is no recent creatinine available.

b-2. When the renography is performed using either furosemide or captopril, list current medications, especially those which may disturb renal hemodynamics and renal transit time (such as a diuretic, an ACEI, angiotensin-receptor blocker, calcium blocker, or non-steroidal anti-inflammatory drug) and interfere in the test interpretation). Sodium dietary restriction may also be indicated.

b-3. Summarize relevant results of recent nephrologic imaging procedures (CT, US, or MRI,) or radionuclide renal test, and date of procedure.

b-4. Summarize any relevant urological procedures (pyeloplasty, stent placement or removal, percutaneous nephrostomy, lithotripsy...) and date of procedure.

## III) Procedure description

- a. Specify any additional hydration in the department (oral, intravenous, type of hydration, volume and timing relative to tracer injection).
- b. Indicate the route of administration and quality of the intravenous bolus injection.
- c. Indicate other drugs used, such as furosemide (F) or captopril, indicating name, dose, route of administration, and delay (min) between radiopharmaceutical administration and image acquisition (e.g., F-15, F0, F + 20, captopril +60, ...).
- d. Indicate whether the patient voided immediately before the image acquisition or not.
- e. Indicate the patient and camera position during acquisition (e.g., supine, posterior).
- f. For renal cortical imaging, indicate the timing of image acquisition relative to the radiopharmaceutical administration.

If necessary: Image the injection site if either a camera-based clearance or a quantitative kidney uptake (as expressed in percentage of the injected activity) measurement if performed.

Measure the voided volume and note the time of voiding to estimate the urine flow rate (diuresis or captopril renography).

Indicate any side effect or complication (e.g., flank pain during diuresis renography or blood pressure drop after captopril) and related treatment.

## IV) Processing:

All background and renal (whole-kidney) ROIs, method of relative renal uptake measurement and transit/drainage parameter calculation, additional ROIs (e.g., parenchymal, pelvic), and other quantitative parameters of uptake and transit/drainage must be visible or described.

### Description of findings

- a. Indicate the quality of the study (e.g., dose extravasation, patient motion).
- b. State the configuration of the kidneys (i.e., size, shape, location, defects, symmetry...).
- c. Describe the image series (e.g., symmetrical and prompt uptake, rapid excretion, no significant retention in the collecting system...).
- d. Specify quantitative parameters.
- e. Relative uptake of the right and left kidneys, expressed as percentages of the total uptake and the normal range
- f. Transit parameters of transit/drainage and their normal ranges
- g. Voided volume, urine flow rate, and residual urine volume, when appropriate

### Cortical renal imaging

- h. Describe the shapes, contours, and uptake homogeneity.
- i. Specify the relative uptake of the right and left kidneys, expressed as percentages of the total uptake and the normal range.

## V) Result display on hard copies

### Dynamic:

- a. A short series of summed images representative of the different phases of the renography. Gray or color scale can be used.
- b. Labelled ROIs on a summed image
- c. Right and left background-corrected renograms, identified by color or line structure, displayed on the same diagram. The renogram curves should express in counts/s and be scaled on the y-axis on the higher peak count.
- d. Radiopharmaceutical and diuresis or captopril renography when appropriate
- e. Relative renal function as expressed in percentages and normal range

- f. Transit parameters (one or two at the most) with their normal ranges

#### Static

- g. All the projections in black white scale, set at the maximum counts into the kidney picture of each image  
h. Relative kidney function as percentage of the total

#### VI) Comments and conclusion

- a. Indicate any study limitation, patient symptom or side-effect.  
b. Recall the indication and specific clinical question.  
c. State in a clear and concise statement either the suspected diagnosis or the answer to the indication for the test.  
d. Differential diagnosis, if appropriate  
e. Recommendations for further diagnostic procedures, if appropriate  
f. Name and reference of the nuclear medicine physician responsible of the test  
g. Requesting physician and other health care providers such as the primary care physician, if appropriate

## Equipment specifications

Gamma camera quality control must follow national rules or the manufacturer's instructions. For further guidance on routine quality control procedures for gamma cameras, refer to the SNMMI Guideline for General Imaging and the EANM guideline on routine quality control for nuclear medicine instrumentation.

## Quality control and improvement

Before processing, image data of the dynamic renal scintigraphy should be first checked for:

1. Motion
2. Sufficient number of counts
3. Extravasation
4. Appearance of activity in the heart ROI
5. Position of the patient
6. Position of the examined organs in the field-of-view

A simple means for the quality control is to run the study in a cine mode. Patient movement, renal uptake of the tracer, transit from parenchyma to pelvis as well as drainage of the collecting systems is easily noted [40]. Motion can be detected either visually (checking that the kidneys remain within the

renal ROIs during the first few minutes after injection) or using special software. Small motion can be corrected by motion-correction software or simply compensated for by drawing kidney ROIs large enough to encompass the motion [43, 52]. Large and complex motion of the patient, motion of the kidneys due to deep breathing, and other physiological movements, often of different size and direction on the left and right sides, and especially an intra-frame motion is difficult or impossible to correct properly with the tools routinely available. Therefore, considerable effort should be made to avoid motion during data acquisition.

Items to be especially considered in the measurement of kidney counts:

- Definition of uptake interval
- Definition of ROIs
- Background subtraction
- Attenuation correction
- Scatter correction

It is assumed that in a normal kidney, a peak renal count rate after background subtraction of approximately 200–250 cps will result in a renogram requiring no or little smoothing prior to interpretation and estimation of relative function [43, 52]. For time-activity curves from the kidney and background ROIs, a formula for the number  $n$  of passes of a  $[1-2-1]$  filter, subject to a minimum of two, has been recommended by Fleming [53].

Required number of counts also depends on type of analysis to be done. More sophisticated methods may need a faster frame rate and higher number of counts than qualitative assessment of the study or simple measurement of relative renal function. Flow (perfusion) study requires higher injected activity to reach sufficient number of counts in the images recorded with the fast frame rate.

Some quantitative methods require specifying time zero from which other time intervals can be measured. Among several alternatives, most authors recommend using peak time of the heart ROI curve because some analytical methods assume regularly decreasing (input) heart curve. The peak of the heart ROI curve thus should be visible on the curve to make sure that data acquisition started before the peak. The raw curve should not start at its maximum in the first frame because then it is not clear whether it is the proper maximum or a point already on the descending part of the curve in case the study was started too late. Before processing, the images or the curve points the peak of the heart curve should be deleted. In a similar way, renal curves should start from zero or nearly zero counts. It is a cross-check in case the heart ROI curve peaks in the first recorded frame.

Extravasation at the site of the injection may give rise to difficulties in data processing and may lead to incorrect interpretation of the study as the shape of ROI curves may

be affected [40]. Assessment of total renal function requires measurement of count rate in the kidneys that is often related to injected counts and expressed as its fraction. If part of administered activity is extravasated or it is delayed at the site of injection, the measurement is inaccurate. Some authors therefore recommend scanning the injection site after the study. If the count rate at the injection site exceeds 1–2% of injected counts, calculation of total renal function should be omitted.

Both kidneys should be at the center of the field of view that should also include both the heart and the bladder wherever it is possible depending on the size of the patient. In many adults, a decision should be made in advance about what position of the field of view is preferred for a diagnosis in a specific patient, whether one including the heart or one including the urinary bladder.

Most frequent errors:

- Patient is fasting before examination
  - Patient is not sufficiently hydrated before examination
  - Urinary bladder is not emptied before examination
  - Injected activity is not measured and recorded
  - Injected activity is too low or too high
  - Part of injected activity extravasated
  - Weight and height of the patient is not measured and recorded
  - Times of activity measurement, injection, and start of the study are not recorded
  - The heart/urinary bladder (depending on the purpose of the study) are outside the field of view
  - Motion of the patient is not prevented
  - Motion of the patient is not recognized and corrected
  - Data acquisition is started too late so that the peak of the heart ROI curve is missed
  - Frame intervals in the uptake phase are too long (> 15 s)
  - The heart ROI is too large
  - The kidney ROIs are too large or too small
  - Background ROIs include part of the kidney, renal pelvis or the ureters
  - Some values of the kidney ROI curve after background subtraction are negative
  - Specified uptake interval starts too early
  - Specified uptake interval ends too late
  - Specified uptake interval includes the peak of the kidney curve
  - Optimal position of uptake interval is not checked with both kidney curves
  - Background counts are not subtracted
  - Subtraction of vascular background is neglected or not performed properly
  - Conjugate (posterior and anterior) views are not checked for registration
  - Geometric mean is improperly calculated
- Post-erect post-voiding images after dynamic renal study are not recorded

## Radiation safety in imaging

The estimated radiation doses for the procedures and agents discussed in this guideline are shown in the tables below:

**Acknowledgments** The authors acknowledge the EANM board, the EANM national delegates, the of the EANM Committees, and members of the SNMMI Committee on Guidelines for their contributions to this manuscript.

The SNMMI Procedure Standards Committee consists of the following individuals:

Dominique Delbeke, MD, PhD, FSNMMI (Chair; Vanderbilt University Medical Center, Nashville, TN); Kevin J. Donohoe, MD (Beth Israel Deaconess Medical Center, Boston, MA); Helena Balon, MD (Beaumont Health System, Royal Oak, MI); Twyla Bartel, DO, MBA, FACNM (Global Advanced Imaging, PLLC, Little Rock, AR); Vasken Dilsizian, MD (University of Maryland Medical Center, Baltimore, MD); James R. Galt, PhD (Emory University Hospital, Atlanta, GA); Jay A. Harolds, MD (Advanced Radiology Services, PC, Grand Rapids, MI); J. Anthony Parker, MD, PhD (Beth Israel Deaconess Medical Center, Boston, MA); Lynne T. Roy, MBA, CNMT, FSNMMI-TS (Cedars/Sinai Medical Center, Los Angeles, CA); Heiko Schoder, MD (Memorial Sloan-Kettering Cancer Center, New York, NY); Barry L. Shulkin, MD, MBA (St. Jude Children's Research Hospital, Memphis, TN); Michael G. Stabin, PhD (Vanderbilt University, Nashville, TN); Mark Tulchinsky, MD, FACNM, CCD (Milton S. Hershey Medical Center, Hershey, PA); Bennett Greenspan, MD, FACNM, FACR (Medical College of Georgia, Augusta, GA); Darko Pucar, MD, PhD (Yale New Haven Hospital, New Haven, CT); David Brandon, MD (Emory University, Atlanta, GA); Erica Cohen, DO, MPH, CCD, FACNM (Edward Hines VA, Hines, IL); Laurel Campbell, BS, CNMT, RT(N)(CT) (Brigham and Women's Hospital, Boston, MA); Perry Gerard, MD (Woodmere, NY); Pradeep Bhambhvani, MD (The University of Alabama at Birmingham, Birmingham, AL); Aaron Jessop, MD, MBA (Vanderbilt University Medical Center, Nashville, TN); Alan Packard, PhD (Boston Children's Hospital/Harvard Medical School, Boston, MA); Amir Khandani, MD (University of North Carolina, Chapel Hill, NC).

The EANM Board consists of the following individuals:

Jolanta Kunikowska, MD, PhD (Nuclear Medicine Department, Medical University of Warsaw, Poland); Francesco Giammarile, MD, PhD (Nuclear Medicine and Diagnostic Imaging Section, International Atomic Energy Agency, Vienna, Austria); Willem J.G. Oyen, MD, PhD (The Institute of Cancer Research and The Royal Marsden NHS Foundation Trust, Department of Nuclear Medicine, London, UK); Jan Pruim, MD, PhD (Medical Imaging Center, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands); Roberto Delgado Bolton, MD, PhD (University Hospital San Pedro, Logroño, La Rioja, Spain); Kristoff Muylle, MD (Universitair Ziekenhuis Brussel-VUB, Brussels, Belgium).

## Compliance with ethical standards

**Approval** These procedures were approved by the SNMMI and EANM Boards.

**Conflict of interest** All authors declare that they have no conflict of interest.

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

## References

- Sfakianakis GN, Sfakianakis ED. Nuclear medicine in pediatric urology. *J Nucl Med*. 1988;29:1287–300.
- Boubaker A, Prior JO, Meuwly JY, Bischof-Delaloye A. Radionuclide investigations of the urinary tract in the era of multimodality imaging. *J Nucl Med*. 2006;47:1819–36.
- De Palma D, Santos AI. Renal radionuclide imaging: an evergreen forty years old. *Klin Padiatr*. 2014;226:225–32.
- Blaufox MD. Procedures of choice in renal nuclear medicine. *J Nucl Med*. 1991;32:1301–9.
- Rado JP, Bano C, Tako J. Radioisotope renography during furosemide (Lasix) diuresis. *Nucl Med Commun*. 1968;7:212–21.
- O'Reilly PH, Testa HJ, Lawson RS, et al. Diuresis renography in equivocal urinary tract obstruction. *Br J Urol*. 1978;50:76–80.
- O'Reilly PH. Diuresis renography: recent advances and recommended protocols. *Br J Urol*. 1992;69:113–20.
- O'Reilly P, Britton K, et al. Consensus report on diuresis renography for investigating the dilated upper urinary tract. *J Nucl Med*. 1996;37:1872–6.
- Taylor AT, Blaufox MD, De Palma D, et al. A guidance document for structured reporting of diuresis renography. *Semin Nucl Med*. 2012;42:41–8.
- Taylor A, Nally J, Aurell M, et al. Consensus report on ACE inhibitor renography for detecting renovascular hypertension. Radionuclides in Nephrourology Group. Consensus group on ACEI renography. *J Nucl Med*. 1996;37(11):1876–82.
- Taylor A. ACE inhibition renography in the evaluation of suspected renovascular hypertension. In: Prigent A, Piepsz A, editors. *Functional imaging in nephrourology*. London: Taylor and Francis; 2006. p. 149–64.
- Prigent A, Chaumet-Riffaud P. Clinical problems in renovascular disease and the role of nuclear medicine. *Semin Nucl Med*. 2014;44:110–22.
- Hilson AJ, Maisey MN, Brown CB, et al. Dynamic renal transplant imaging with Tc-99m DTPA (Sn) supplemented by a transplant perfusion index in the management of renal transplants. *J Nucl Med*. 1978;19(9):994–1000.
- Kirchner PT, Goldman MH, Leapman SB, Kiepfer RF. Clinical application of the kidney to aortic blood flow index (K/A ratio). *Contrib Nephrol*. 1978;11:120–6.
- Li Y, Russell CD, Palmer-Lawrence J, Dubovsky EV. Quantitation of renal parenchymal retention of technetium-99m-MAG3 in renal transplants. *J Nucl Med*. 1994;35(5):846–50.
- Dubovsky EV, Russell CD, Bischof-Delaloye A, et al. Report of the radionuclides in Nephrourology committee for evaluation of transplanted kidney (review of techniques). *Semin Nucl Med*. 1999;29(2):175–88.
- De Palma D, Manzoni GA. Different imaging strategies in febrile urinary tract infection in childhood. What, when, why? *Pediatr Radiol*. 2013;43(4):436–43.
- Tubis M, Posnick E, Nordyke RA. Preparation and use of I-131 labeled sodium iodohippurate in kidney function test. *Proc Soc Exp Biol Med*. 1960;103:497–8.
- Fritzberg AR, Kasina S, Eshima D, Johnson DL. Synthesis and biological evaluation of Tc-99m MAG3 as a hippuran replacement. *J Nucl Med*. 1986;27:111–6.
- Russell CD, Dubovsky EV. Reproducibility of single-sample clearance of 99mTc-mercaptoacetyltriglycine and 131I-Orthoiodohippurate. *J Nucl Med*. 1999;40:1122–4.
- Müller-Suur R, Müller-Suur C. Glomerular filtration and tubular secretion of MAG-3 in the rat kidney. *J Nucl Med*. 1989;30(12):1986–91.
- Bubeck B, Brandau W, Eisenhuth M, et al. The tubular extraction rate (TER) of Tc-99m MAG3: a new quantitative parameter for renal parameter of renal function. *Nucl Compact*. 1987;18:260–7.
- Hauser W, Atkins HL, Nelson KG, Richards P. Technetium-99m DTPA: a new radiopharmaceutical for brain and kidney scanning. *Radiology*. 1970;94(Issue 3).
- Chantler C, Barratt TM. Estimation of glomerular filtration rate from plasma clearance of 51Cr-edetic acid. *Arch Dis Child*. 1972;47:613–7.
- Stacy BD, Thorburn GD. Chromium-51 ethylenediaminetetraacetate for estimation of glomerular filtration rate. *Science*. 1966;152(3725):1076–7.
- Boyd RE, Robson J, Hunt FC, et al. 99mTc gluconate complexes for renal scintigraphy. *Br J Radiol*. 1973;46(548):604–12.
- Lin TH, Khentigan A, Winchell HS. A 99mTc-chelate substitute for organoradiomercurial renal agents. *J Nucl Med*. 1974;15(1):34–5.
- Willis KW, Martinez DA, Hedley-Whyte ET, et al. Renal localization of 99mTc-stannous glucoheptonate and 99mTc-stannous dimercaptosuccinate in the rat by frozen section autoradiography. The efficiency and resolution of technetium-99m. *Radiat Res*. 1977;69(3):475–88.
- Yee CA, Lee HB, Blaufox MD. DMSA renal uptake: influence of biochemical and physiologic factors. *J Nucl Med*. 1981;22(12):1054–8.
- ICRP publication 80. Absorbed doses. Radiation dose to patients from radiopharmaceuticals. Addendum 2 to ICRP publication. Oxford: Pergamon Press; 1998.
- Stabin M, Taylor A, Eshima D, et al. Radiation dosimetry for technetium-99m-DTPA, and iodine-131-OIH based on human biodistribution studies. *J Nucl Med*. 1992;33:33–40.
- Fommei E, Ghione S, Hilson AJW, et al. Captopril radionuclide test in renovascular hypertension: a European multicentre study. *Eur J Nucl Med*. 1993;20:617–23.
- Taylor AT Jr, Fletcher JW, Nally JV Jr, et al. Procedure guideline for diagnosis of renovascular hypertension. Society of Nuclear Medicine. *J Nucl Med*. 1998;39(7):1297–302.
- Piepsz A, Colarinho P, Gordon I, et al. Guidelines for 99mTc-DMSA scintigraphy in children. *Eur J Nucl Med*. 2001;28(3):BP37–41. Revision 2010 on line
- Piepsz A, Dobbeleir A, Ham HR. Effect of background correction on separate technetium-99m-DTPA renal clearance. *J Nucl Med*. 1990;31:430–5.
- Lythgoe MF, Gordon I, Khader Z, et al. Assessment of various parameters in the estimation of differential renal function using technetium-99m mercaptoacetyltriglycine. *Eur J Nucl Med*. 1999;26:155–62.
- Lezaic L, Hodolic M, Fettich J, et al. Reproducibility of 99mTc-mercaptoacetyltriglycine renography: population comparison. *Nucl Med Commun*. 2008;29:695–704.
- Caglar M, Gedik GK, Karabulut E. Differential renal function estimation by dynamic renal scintigraphy: influence of background definition and radiopharmaceutical. *Nucl Med Commun*. 2008;29:1002–5.
- Rutland MD. Glomerular filtration rate using 99mTc DTPA and a gamma camera. *Eur J Nucl Med*. 1983;4:425–33.
- Gordon I, Piepsz A, Sixt R. Guidelines for standard and diuretic renogram in children. *Eur J Nucl Med Mol Imaging*. 2011;38(6):1175–88.
- Blaufox MD. Editorial comments: renal background correction and measurement of split renal function: the challenge. *Eur J Nucl Med Mol Imaging*. 2016;43:548–9.
- Fine EJ, Blaufox MD, On Behalf of the Albert Einstein College of Medicine/Cornell University Medical Center Collaborative Hypertension Group. The Einstein/Cornell collaborative protocol to assess efficacy and methodology in captopril scintirenography. *Am J Hypertens*. 1991;4:716S–20S.

43. Prigent A, Cosgriff P, Gates GF, et al. Consensus report on quality control of quantitative measurements of renal function obtained from the renogram: international consensus committee from the scientific Committee of Radionuclides in Nephrourology. *Semin Nucl Med.* 1999;29(2):146–59.
44. Delpassand ES, Homayoon K, Madden T, et al. Determination of glomerular filtration rate using a dual-detector gamma camera and the geometric mean of renal activity: correlation with the Tc-99m DTPA plasma clearance method. *Clin Nucl Med.* 2000;25(4):258–62.
45. Blaufox MD, Aurell M, Bubeck B, et al. Report of the radionuclides in nephrourology committee on renal clearance. *J Nucl Med.* 1996;37(11):1883–90.
46. Gates GF. Glomerular filtration rate: estimation from fractional renal accumulation of 99mTc-DTPA (stannous). *AJR Am J Roentgenol.* 1982;138(3):565–70.
47. Schlegel JU, Hamway SA. Individual renal plasma flow determination in 2 minutes. *J Urol.* 1976;116(3):282–5.
48. Tauxe WN, Dubovsky EV, Kidd T Jr, et al. New formulas for the calculation of effective renal plasma flow. *Eur J Nucl Med.* 1982;7(2):51–4.
49. Taylor A Jr, Corrigan PL, Galt J, et al. Measuring technetium-99m-MAG3 clearance with an improved camera-based method. *J Nucl Med.* 1995;36:1689–95.
50. Piepsz A, Colarinha P, Gordon I, et al. Guidelines for glomerular filtration rate determination in children. *Eur J Nucl Med.* 2001;28(3):BP31–6.
51. Itoh K. Comparison of methods for determination of glomerular filtration rate: Tc-99m-DTPA renography, predicted creatinine clearance method and plasma sample method. *Ann Nucl Med.* 2003;17(7):561–5.
52. Cosgriff PS, Lawson RS, Nimmon CC. Towards standardization in gamma camera renography. *Nucl Med Commun.* 1992;13:580–5.
53. Fleming JS. A technique for analysis of geometric mean renography. *Nucl Med Commun.* 2006;27:701–8.

## Affiliations

M. Donald Blaufox<sup>1</sup> · Diego De Palma<sup>2</sup>  · Andrew Taylor<sup>3</sup> · Zsolt Szabo<sup>4</sup> · Alain Prigent<sup>5</sup> · Martin Samal<sup>6</sup> · Yi Li<sup>7</sup> · Andrea Santos<sup>8</sup> · Giorgio Testanera<sup>9</sup> · Mark Tulchinsky<sup>10</sup>

<sup>1</sup> Department of Nuclear Medicine, Albert Einstein College of Medicine, and Montefiore Medical Center, New York, NY, USA

<sup>2</sup> Nuclear Medicine Service, ASST-Settelaghi, Varese, Italy

<sup>3</sup> Radiology and Imaging Sciences, Emory University School of Medicine, Atlanta, GA, USA

<sup>4</sup> The Russell H. Morgan Department of Radiology and Radiological Science, Johns Hopkins Medical Institutions, Baltimore, MD, USA

<sup>5</sup> Biophysics and Nuclear Medicine Department, Bicêtre Hospital, University of Paris-Sud, Paris, France

<sup>6</sup> Department of Nuclear Medicine, First Faculty of Medicine, Charles University Prague, Prague, Czech Republic

<sup>7</sup> Division of Nuclear Medicine, Department of Radiology, Philadelphia VA Medical Center, Philadelphia, PA, USA

<sup>8</sup> Hospital Cuf Descobertas, Lisbon, Portugal

<sup>9</sup> Barts Health NHS Trust, Department of Nuclear Medicine, St Bartholomew's Hospital, London, UK

<sup>10</sup> MS Hershey Medical Center, Penn State University, Hershey, PA, USA