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# **THE SNMMI AND EANM PRACTICE GUIDELINE FOR RENAL SCINTIGRAPHY IN ADULTS**

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### **Keywords:**

### **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.

## **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 (Sfakianakis, 1988). This information supplements that obtained by other imaging methods (Ultrasound, CT, MRI) (Boubaker 2006, De Palma 2014), it has special value 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 may provide useful morphologic information.

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

## **GOALS**

Purpose of this guideline is to provide practitioners a summary of radiopharmaceuticals, techniques and clinical indications for performing renal scintigraphy in adults. This state-of-the-art overview will not deal with radiopharmaceuticals or indications currently under investigation or used for clinical trials or research.

## **DEFINITIONS**

Not applicable

## **COMMON CLINICAL INDICATIONS**

Major indications (Blaufox 1991) for renal scintigraphy include but are not limited, to the following:

- Calculation of differential (relative) renal function,
- Measurement of the absolute renal function, either as an approximation of effective renal plasma flow (ERPF) or glomerular filtration rate (GFR).
- Congenital and acquired renal abnormalities
- Acute renal failure
- Obstructive uropathy
- Renovascular hypertension
- Status post renal transplantation
- Pyelonephritis and parenchymal scarring

**Optimal assessment of the existence of obstructive uropathy usually requires diuretic renography (Rado JP, et al 1968, O'Reilly PH, et al 1978, 1992, 1996), i.e. the use of a diuretic drug, such as furosemide, to initiate a 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 causes of a dilated renal pelvis (Taylor 2012).** Diuretic renography is a non-invasive equivalent to the now discarded Whitaker test, which directly measures the intrarenal pelvic hydrostatic pressure. There is a full guideline in preparation devoted to obstructive uropathy.

In the case of suspected renovascular hypertension, it is recommended to perform an angiotensin-converting enzyme inhibition (ACEI) renogram. This was first described in 1983 by Majd et al (Majd M, et al 1983). This test helps diagnose renal vascular hypertension caused by renal artery stenosis (RAS) and may predict the response to vascular intervention. ACEI renography has been used as a routine nuclear medicine exam for many years. In the era of CT angiography, MR angiography and Doppler vascular sonography the role of captopril renography has diminished (Taylor A. 1996, 2006; Prigent 2014).

The renal transplant with ATN has poor renal function with evidence of renal cortical retention of MAG3, reduced renal uptake of DTPA and reduced urine excretion with images showing blood perfusion relatively preserved compared to function (Hilson AJ et al 1978, Kirchner PT et al 1978, Li Y, Russell CD, et al 1994). Quantitative methods may be useful in follow-up studies. There are a variety of methods proposed to evaluate blood flow of the transplant kidney, including Hilson et al's perfusion index and Kirchner et al's kidney-to-aorta (K/A) ratio (Hilson AJ et al 1978, Kirchner PT et al 1978). There are quantitative methods for measurement of renal parenchymal (cortical) retention of tubular radiotracers (MAG3 and OIH), such as T<sub>max</sub> and 20/3 min ratio (Li Y, Russell CD, et al 1994) which increase in ATN of the graft. A comprehensive review was published by Dubovsky et al. (1999)

1. Urinary tract infections (UTI) are often clinically only divided into febrile or non-febrile. Tc-99m DMSA is the best imaging agent to visualize renal parenchymal pathology, helping to distinguish pyelonephritis from lower tract infections acutely. Renal cortical scintigraphy may be performed to evaluate kidney scarring after pyelonephritis. Scarring should not be assessed less than six months after the last febrile UTI. (De Palma, 2013)

2.

## **QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL**

In the United States, 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. In particular, the nuclear medicine physician should be aware of relevant urologic procedures and surgeries such as the presence of a nephrostomy tube, ureteral stent or urinary diversion. The supervising/interpreting nuclear medicine physician should review all available clinical, laboratory, and radiologic data prior to performing the study.

### **A. Patient preparation and precautions**

Renal radionuclide scans generally require no specific preparation: patients can avoid fasting, and drinking at least 500 ml of water is recommended. Pregnancy is a usually a contraindication to radiopharmaceutical administration. Adverse reactions to renal radiopharmaceuticals are quite rare: no major reaction has ever been reported

### **B. Radiopharmaceuticals**

When performing dynamic renal studies, the radiopharmaceuticals can be sub-divided into two categories: 1: High extraction renal plasma flow (ERPF) agents (tubular extraction) including <sup>131</sup>I-hippuran, <sup>123</sup>I-hippuran, <sup>99m</sup>Tc-MAG3 (mercaptoacetyl-triglycerine) and <sup>99m</sup>Tc-EC (ethylenedicysteine).

and 2: glomerular filtration agents, including <sup>99m</sup>Tc-DTPA (diethylenetriamine pentaacetic acid) and <sup>51</sup>-Cr EDTA (ethylenediamine tetraacetic acid)

The radiopharmaceuticals used for renal morphologic scintigraphy, are <sup>99m</sup>Tc-DMSA (dimercaptosuccinic acid) and <sup>99m</sup>Tc-glucoheptonate, both of which accumulate primarily in the renal cortex.

I-131/123 orthoiodohippuran (OIH), a classic renal tubular agent that has been used as a substitute for para-aminohippurate (PAH), was introduced by Tubis (Tubis M, et al, 1960). The <sup>131</sup>-I label, once used for probe renography, yields very low quality images with a high radiation dose and is no longer available.

<sup>99m</sup>Tc-MAG3 (Fritzberg AR, et al, 1986), is similar to OIH (Russell, 1999), although it has very little glomerular filtration due to its high plasma protein binding, that results in a lower extraction fraction. (Muller-Suur, 1989). <sup>99m</sup>Tc-MAG3 is currently the most frequently used <sup>99m</sup>Tc-labelled renal tubular agent in nuclear medicine practice. Since its excretion is more comparable to the secretion rate of proximal renal tubule, Bubeck et al proposed the concept of tubular extraction rate (TER) (Bubeck B, et al, 1987) to replace the term ERPF.

<sup>99m</sup>Tc-DTPA is excreted by glomerular filtration without renal tubular secretion, similar to inulin and creatinine, and was first used clinically in 1970 (Hauser W. et al 1970). There is only 5-10% protein bound DTPA in the plasma after 1 hour. DTPA labelled with <sup>99m</sup>Tc remains the most suitable radiopharmaceutical for combined measurement of GFR and renal imaging.

Cr-51 EDTA also has been commonly used in Europe since 1966 to measure GFR (Stacy BD 1966, Chantler, 1972), It is not available in the US and it cannot be used for imaging.

Tc-99m DMSA (dimercaptosuccinic acid) (Lin TH, et al 1974) and Tc-99m GH (glucoheptonate) (Boyd RE. et al 1973) 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 demonstrate renal mass or defects in the renal parenchyma. These agents are also called renal cortical agents. 99mTc-DMSA is commonly used because of its higher retention in the renal parenchyma (30% vs 5-10% of glucoheptonate). (Willis, 1977) These numbers are approximations and there is some evidence of secretion of DMSA by the distal tubule (Yee et al 1981). Because of its high retention the potential radiation dose of DMSA is significant and the administered dose should be chosen with that in mind.

## **PROTOCOL/IMAGE ACQUISITION**

### **Static Renal Scan (sometimes referred as Renal Cortical scintigraphy)**

Radiopharmaceutical and injected activity: 99mTc-DMSA provides the best images. 99mTc-Glucoheptonate has been used also.

Adult Dose: 100 MBq

Radiation burden: approximately 1mSv (ICRP 80, 1998).

*General procedure:*

All relevant available clinical, biochemical and imaging information must be collected.

#### 3. Patient preparation:

Good hydration before and after radiopharmaceutical administration

Radiopharmaceutical Administration:

Intravenous injection must be performed, carefully avoiding extravasation.

Timing after injection:

Image acquisition should start from 2 to 4 hours after radiopharmaceutical administration. In the presence of poor renal function late images (up to 20 hours after) can be acquired.

Patient Positioning

Supine position: Be careful with patient comfort to reduce motion.

Technical Parameters: Static image acquisition

Collimator: Low energy, ultra-high Resolution

Minimum Matrix for dynamic scan: 128x128 or 256x256 pixel (newer instruments permit much greater resolution)

Total counts/ Time per view: At least 300 000 total counts must be acquired or use fixed time of 5-10 minutes/ per view. If a pinhole collimator is being used, 100 000 to 150 000 total counts or 10 minutes should be acquired per view.

Views: Posterior and 30°-35° Posterior Obliques. Anterior view must be considered if there are abnormalities of number, shape and position of the kidneys. SPECT images can be acquired but there is no consensus in its usefulness (Piepsz, 2001)

After Imaging:

Patient should be advised to maintain hydration and frequent bladder emptying during the rest of the day.

### **Renal dynamic scintigraphy**

Renal dynamic scintigraphy (radionuclide renography) consists of serial imaging after intravenous administration of the selected radiopharmaceutical. This procedure usually involves 2 serial dynamic acquisitions, the first intended to investigate vascular or perfusion phase (this phase is

often omitted), followed by the second one to evaluate functional uptake, cortical transit, and excretion. It is recommended also to obtain a later static image after upright standing and bladder voiding. Although these phases are often discussed separately, they all take place virtually simultaneously.

#### Patient preparation:

Good hydration before and after radiopharmaceutical administration is essential. The patient should void before the beginning of the scan. Adult Dose:  $^{99m}\text{Tc}$ -labeled radiopharmaceuticals: from 90 to 200 MBq. The higher activity is suggested for studying renal perfusion,

We strongly recommend optimizing protocols according to the ALARA principles

Radiation burden: usually, approximately less than 1mSv with the above suggested activities. (ICRP 80, 1998; Stabin, 1992). Specific information is detailed in Tables 1 and 2.

#### *General procedure:*

All relevant clinical, biochemical and imaging information must be collected.

#### Radiopharmaceutical administration

Intravenous injection should be performed. A butterfly needle is recommended to avoid extravasation. If indicated by clinical indications, furosemide intravenous administration can be performed. The suggested dose is 0.5 mg/kg of body weight, max 40 mg. The simplest practice is to administer the diuretic at the same time as the radiopharmaceutical (so called F+0 protocol). Other options include 20 minutes after radiopharmaceutical injection or 15 minutes before radiopharmaceutical injection (so called F+20 or F-15 protocols). Interpretation of the results must take into account the chosen timing.

Renovascular hypertension scintigraphy is performed approximately 1 hour after oral administration of 25 to 50 milligrams of captopril or 10 to 20 minutes after intravenous injection of 40 micrograms/kg (maximum 2.5 mg) of enalaprilat. Blood pressure should be measured before administration of the ACE inhibitor and monitored every 10 to 15 minutes. An intravenous line should be considered to be kept in place to allow prompt fluid replacement if the patient becomes hypotensive. The patient should be well hydrated, especially if furosemide is also used to facilitate detection of cortical retention of the radiopharmaceutical. One protocol is to obtain a baseline scan without an ACE inhibitor followed by a repeat examination after administration of an ACE inhibitor on the same or following day. The combined examinations help to detect significant ACE inhibitor induced scintigraphic abnormalities. (Fommei, 1993, Taylor AT Jr, et al 1998)

An alternative protocol is to obtain the examination with an ACE inhibitor first. A normal examination indicates a low probability for renovascular hypertension and obviates the need for a baseline examination without an ACE inhibitor. If the examination with an ACE inhibitor is abnormal, a baseline examination is needed as further investigation waiting at least the next day or later. Chronic use of ACE inhibitors may decrease the sensitivity of the test. ACE inhibitors should be discontinued for 3 to 7 days before the test, depending on their half-life. If stopping the patient's ACE inhibitor is not possible, the study may still be performed. (Fommei, 1993) but the sensitivity is decreased.

#### Timing after injection and scan framing:

A commonly used technique involves dynamic acquisition of 1-2 second images for 1 min. (vascular phase (first phase)), starting immediately after radiopharmaceutical administration. It is followed by 10-20 second images (functional uptake cortical transit (second phase)), and then 20-30 sec. images (excretion phases (third phase)). Always acquire a post-micturition post-erect image, for the same duration as the last frame of the renogram. The compatibility between the acquisition protocol and the processing software must be checked in advance.

#### Patient Positioning

Supine position: Be careful with patient comfort, to reduce motion. In patients who cannot lie flat it is possible to perform the exam seated with the back on gamma-camera detector, but this may lead to important errors

Technical Parameters

Dynamic image acquisition

Collimator: [Low Energy – High resolution or General purpose, according to availability]

Minimum Matrix: 64x64 or 128 x128 pixel

Views: Posterior. Anterior views must be acquired in the presence of horseshoe or ectopic kidney or in other situations where the kidney is anterior such as kidney allograft evaluation. Lateral views may be obtained at the end of the renography if renal depth measurements are needed.

Frame time (first phase): 1-5 seconds/frame for 1 minute

Frame time (second phase): 10-20 seconds/frame for 5-10 minutes

Frame time (third phase): 20-30 seconds/frame for at least 20 min

Total max time 20-30 minutes

Additional images after bladder emptying or delayed post-erect images, of the same duration as the last frame of the renogram are useful.

After Imaging

Patient should be advised to maintain hydration and frequent bladder emptying during the rest of the day.

## **Processing**

### **Split (relative, differential) renal function**

The accuracy and reproducibility of the measurement of split renal function (SRF) depends on kidney size and kidney function. 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 [Piepsz, 1990; Lythgoe, 1999; Caglar, 2008; Lezaic, 2008].

The measurement of SRF with static renal scintigraphy requires drawing a region of interest (ROI) around each kidney to calculate the percent contribution of each kidney counts to total counts. 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 (Piepsz,2001) Unfortunately, in the case of poor renal function the errors of the measurement increase. (Fine EJ, Blaufox MD On Behalf of the Albert Einstein College of Medicine/Cornell University Medical Center Collaborative Hypertension Group 1991)

The measurement of SRF with dynamic renal scintigraphy requires drawing a region of interest (ROIs) 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' for 99mTc MAG3 or EC

120'-180' for 99mTc DTPA

There are two models of equivalent accuracy; the slope method with the Patlak-Rutland (Rutland, 1983) plot and the integral method. (Gordon, 2011) A recent report suggests a method using liver activity to help with the normalization but it has not yet been confirmed fully (Blauxox 2016)

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 (Prigent, 1999). It is necessary to correct for attenuation in the 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, using a two head gamma camera for the scan (Delpassand, 2000)

### **Total (absolute) renal function (In Vitro methods)**

Total renal function may be performed with renal scintigraphy to obtain quantitative functional data. The measurement of absolute renal function (GFR and ERPF) using radionuclides is a unique technique to assess renal function. This is a non-invasive and accurate methodology (Blauxox 1996). Several methods have been introduced for this purpose (Schlegel, 1976, Tauxe, 1982, Gates, 1982, Bubeck, 1987, Taylor, 1995, Itoh, 2003); the timing of the blood samples depends on the radiopharmaceutical injected.

### **Interpretation**

Interpretation of the scan is highly dependent on the radiopharmaceutical used for imaging. The radiopharmaceutical that is most frequently used at present is Tc-99m MAG3 (mercaptoacetyltriglycine). Tc-99m DTPA (diethyl-triamino-pentaacetic acid) can be in most situations for the same indications but the images are not as good and there is greater background. This disadvantage is offset to some degree by the lower associated radiation dose. The renal clearance of Tc-99m DTPA approximates the glomerular filtration rate (GFR).. The first phase provides a qualitative assessment of renal blood flow 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.

Tc-99m MAG3 is bound by plasma protein significantly so that its glomerular filtration is minimal while the effective extraction fraction is about 50-60 %. Tc-99m MAG3 is preferred over Tc-99m 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 because of the radiation associated with a high dose, it is more effective in detecting renal outflow obstruction, renal transplant dysfunction, renal trauma and posttraumatic or iatrogenic urinary leaks.

Nephrotoxic drugs can prolong parenchymal radiotracer transit and depending on the severity of damage and also result in reduced parenchymal uptake. Nephrotoxic drugs include cyclosporine, aminoglycosides and cytotoxic chemotherapy drugs. Most cytotoxic drugs cause tubulo-interstitial injury: carboplatin, cetuximab, cyclophosphamide, ifosfamide, interferons, methotrexate, pantumumab, streptozocin. Others affect the vasculature and renal perfusion: bevacizumab, gemcitabine, interleukin 2, mitomycin C, nitrosoureas, sorafenib, sunitinib.

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



Pseudo-tumors of the kidneys are non-malignant masses that can mimic renal tumors. They can have a developmental etiology with normal parenchymal function such as persistent fetal lobulation, dromedary hump, or prominent columns of Bertin. Infectious / inflammatory diseases will result in reduced parenchymal function. Infectious diseases with renal cortical defects on the scan include focal pyelonephritis, renal abscess, and post pyelonephritic scarring. Examples of inflammatory diseases with focally or regionally decreased parenchymal function are xanthogranulomatous pyelonephritis and sarcoidosis. Other examples of renal pseudo tumors with decreased parenchymal function are arteriovenous malformations, hematomas and extramedullary hematopoiesis.

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. Another important cause of urinoma is renal trauma. 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 provides localization of a urinoma.

## **SPECIAL CONSIDERATIONS FOR CHILDREN**

See Pediatric guidelines

## **VII. 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 (1-5).

### **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 dose and identity of radiopharmaceutical

### **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 diuretic, angiotensin-converting enzyme inhibitor or angiotensin-receptor blocker, calcium blocker, non-steroidal anti-inflammatory drug) and interfere in the test interpretation). Similarly indicate sodium dietary restriction.

b-3. Summarize relevant results of recent nephrourologic imaging procedures (CT, US, MRI, etc.) 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).

a. Radiopharmaceutical

State the name of radiopharmaceutical and type of tracer:

**Glomerular filtration tracer,**

99mTc- diethylenetriaminepentaacetic acid (DTPA)

**Tubular secretion tracer,**

99mTc mercaptoacetyltriglycine (mertiatide) (MAG3),

99mTc L,L - ethylenedicysteine (EC),

131I- or 123I- orthoiodohippurate (OIH), (not in general use)

99mTc-(CO<sub>3</sub>) tricarbonylnitriloacetic acid (NTA, not commercially available).

**Retention tracer,**

99mTc-dimercaptosuccinic acid (DMSA)

99mTc-glucoheptonate (GH)

c. Indicate administered activity (“dose”) in MBq . Consider estimation of the effective dose as expressed in mSv and the equivalence in terms of percentage of the yearly natural radiation or effective dose of thorax-abdomen-pelvis CT is recommended.

d. Indicate the route of administration and quality of the IV bolus injection.

e. Indicate other drugs used, such as furosemide (see guideline on obstructive uropathy) or captopril (see guideline on renovascular hypertension). Indicate name, dose, route of administration, and delay (min) between radiopharmaceutical administration and image acquisition (e.g., F-15, F0, F+20, captopril + 60, ...).

f. Indicate whether the patient voided immediately before the image acquisition or not (especially for renography).

Indicate the patient position during acquisition (e.g., supine)

h. Indicate the timing of image acquisition relative to the radiopharmaceutical administration (especially for renal cortical imaging).

Describe the imaging procedure

Dynamic acquisition:..., frame time (in seconds), duration (in minutes), and views (e.g., posterior for renography, anterior for transplant evaluation).

Post void acquisition upright for a few minutes (diuresis renography).

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.

Static acquisition: delay between DMSA injection and image acquisition, and either frame time and positions (e.g., posterior and oblique's) or SPECT.

- j. Measure the voided volume and note the time of voiding to estimate the urine flow rate (diuresis or captopril renography).
- k. Indicate any side effect or complication (e.g., flank pain during diuresis renography or blood pressure drop after captopril,...) and related treatment.

Processing:

Describe background and renal (whole-kidney) regions of interest (ROIs) and method of relative renal uptake measurement and transit/drainage parameter calculation.

Describe additional ROIs (e.g., parenchymal, pelvic) and other quantitative parameters of uptake and transit/drainage.

Description of findings

Indicate the quality of the study (e.g., dose extravasation, patient motion,..)

State the configuration of the kidneys (i.e., size, shape, location, defects, symmetry...)

Describe the image series (e.g., symmetrical and prompt uptake, rapid excretion, no significant retention in the collecting system...)

Specify quantitative parameters

Relative uptake of the right and left kidneys, expressed as percentages of the total uptake and the normal range.

Transit parameters of transit/drainage and their normal ranges

Voided volume, urine flow rate and residual urine volume, when appropriate

Cortical renal imaging

Describe the shapes, contours, uptake homogeneity,

Specify the relative uptake of the right and left kidneys, expressed as percentages of the total uptake and the normal range.

Impression and result display on hard copies

Name of the patient, date of birth and date of the test

Radiopharmaceutical and diuresis or captopril renography when appropriate

Relative renal function as expressed in percentages and normal range

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

A short series of summed images representative of the different phases of the renography. Gray or color scale can be used.

Labelled ROIs on a summed image

Right and left background-corrected renograms, identified by color or line structure, displayed on the same diagram. The renogram curves should express in counts/sec and scaled on the y-axis on the higher peak count.

Comments and conclusion

Indicate any study limitation, patient symptom or side-effect

Recall the indication and specific clinical question

State in as clear (e.g., avoid "...consistent with...") and concise a statement as possible either the suspected diagnosis or the answer to the indication for the test.

Differential diagnosis, if appropriate

Recommendations for further diagnostic procedures, if appropriate

Name and reference of the nuclear medicine physician responsible of the test.

Requesting physician, and other health care providers such as the primary care physician, if appropriate

## VIII. EQUIPMENT SPECIFICATIONS

### IX QUALITY CONTROL AND IMPROVEMENT

Before processing, image data of dynamic renal scintigraphy should be first checked for sufficient number of counts (signal-to-noise ratio), extravasation, appearance of activity in the heart, position of the patient and of examined organs in the field of view and for motion. 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 thus easily noted [Gordon 2011].

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 [Cosgriff 1992, Prigent 1999]. 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 [Fleming 2006]

Required number of counts also depends on type of analysis to be done. More sophisticated methods may need 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. Improving sensitivity of modern gamma cameras allows for sufficient number of counts to be achieved with lower administered activity. However, quantitative studies to derive new minimum activity levels in both children and adults remain to be done.

Some quantitative methods require specifying time zero from which other time intervals can be measured. Of several alternatives, most authors recommend to use peak time of the heart ROI curve because some analytical methods assume monotonously 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. In other words, 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 before 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 [Gordon 2011]. 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 injected extravasously 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 with respect to the size of the patient. In many adults, a

decision has to be made in advance 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. 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 usually well corrected by motion-correction software or simply compensated by drawing kidney ROIs large enough to encompass the motion [Cosgriff 1992, Prigent 1999]. 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 are difficult or impossible to correct properly with the tools routinely available. Therefore considerable effort should be made to avoid motion during data acquisition.

#### 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 is administered extravenously
- 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 ( $> 10$  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
- measurement of split renal function and other indices is performed only once
- number of measurements, arithmetic mean value and its variance are not reported
- conjugate (posterior and anterior) views are not checked for registration
- geometric mean is improperly calculated
- posterior view is not corrected for table attenuation
- post-erect post-voiding images after dynamic renal study are not recorded

#### Image data should be checked for

- sufficient number of counts
- extravasation

- appearance of activity in the heart ROI
- position of the patient
- position of the examined organs in the FOV
- motion

Items to be especially considered in the measurement of kidney counts

- definition of uptake interval
- definition of ROIs
- background subtraction
- attenuation correction
- scatter correction

## X. SAFETY CONFECTION CONTROL AND PATIENT EDUCATIONS CONCERNS

### XI. RADIATION SAFETY IN IMAGING

An SNM guideline on dosimetry is being developed. When approved and available this guideline will supersede the radiation dosimetry tables in individual guidelines. Approval for each guideline should be obtained from the EANM Dosimetry Committee during the guideline writing process. The values for the radiation dosimetry tables are usually readily available from the SNM MIRDC committee, ICRP 54 and its addenda. The estimated radiation doses for the procedures and agents discussed in this guideline are shown in the tables below:

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	0.18	0.67	0.0088	0.033
<sup>99m</sup> Tc DTPA*	185	370	5.0	10.0	Bladder	0.062	0.23	0.0049	0.018
<sup>99m</sup> Tc EC*	185	370	5.0	10.0	Bladder	0.095	0.35	0.0063	0.024
<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	0.11	0.41	0.0070	0.026

\*Data are from (ICRP Publication 106. Radiation Dose to Patients from Radiopharmaceuticals - Addendum 3 to ICRP Publication 53. Ann. ICRP 38 (1-2), 2008)

†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.)

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*	3.4x10 <sup>-3</sup>	2.6x10 <sup>-3</sup>	1.3x10 <sup>-3</sup>	1.2x10 <sup>-3</sup>
<sup>123</sup> I Hippuran†	3.1x10 <sup>-2</sup>	2.4x10 <sup>-2</sup>	8.4x10 <sup>-3</sup>	7.9x10 <sup>-3</sup>
<sup>131</sup> I Hippuran†	6.4x10 <sup>-2</sup>	5.0x10 <sup>-2</sup>	1.9x10 <sup>-2</sup>	1.8x10 <sup>-2</sup>
<sup>99m</sup> Tc DMSA†	5.1x10 <sup>-3</sup>	4.7x10 <sup>-3</sup>	4.0x10 <sup>-3</sup>	3.4x10 <sup>-3</sup>
<sup>99m</sup> Tc DTPA†	1.2x10 <sup>-2</sup>	8.7x10 <sup>-3</sup>	4.1x10 <sup>-3</sup>	4.7x10 <sup>-3</sup>
<sup>99m</sup> Tc EC*	1.3x10 <sup>-2</sup>	9.7x10 <sup>-3</sup>	4.0x10 <sup>-3</sup>	3.8x10 <sup>-3</sup>
<sup>99m</sup> Tc Glucoheptonate†	1.2x10 <sup>-2</sup>	1.1x10 <sup>-2</sup>	5.3x10 <sup>-3</sup>	4.6x10 <sup>-3</sup>
<sup>99m</sup> Tc MAG3†	1.8x10 <sup>-2</sup>	1.4x10 <sup>-2</sup>	5.5x10 <sup>-3</sup>	5.2x10 <sup>-3</sup>

\*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

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### **XIII. APPROVAL**

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