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.

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.

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 those entities not providing these services is not authorized.

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THE SNMMI AND EANM PRACTICE GUIDELINE FOR RENAL SCINTIGRAPHY IN ADULTS

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I. 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.

II. 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), 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.

III. GOALS

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.

IV. DEFINITIONS

Not applicable

V. COMMON CLINICAL INDICATIONS

Major indications (Blaufox 1991) 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 (Rado JP, el al 1968, O'Reilly PH, et al 1978, 1992, 1996), 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 causes of a dilated renal pelvis (Taylor 2012). 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 inhibition (ACEI) renogram. In the era of CT angiography, MR angiography and Doppler vascular sonography the role of ACE (captopril) renography has diminished (Taylor A. 1996, 2006; Prigent 2014). 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 ATN, the latter characterized by images showing relatively preserved renal perfusion in comparison to function (Hilson AJ et al 1978, Kirchner PT et al 1978, Li Y, Russell CD, et al 1994). A comprehensive review was published by Dubovsky et al. (1999)

Urinary tract infections (UTI) often are clinically divided into febrile or non-febrile. 99m-Tc-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 six months after the last febrile UTI. (De Palma, 2013)

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VI. 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.

VII. 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 GFR determination using 51-Cr-EDTA if needed (see 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-Tc-MAG3 (mercaptoacetyl-triglycine) and 99m-Tc-EC (ethylenecysteine).
2. Glomerular filtration agents, including 99m-Tc-DTPA (diethylenetriamine pentaacetic acid) and 51-Cr EDTA (ethylene-diamine tetraacetic acid)

Radiopharmaceuticals for static scintigraphy are 99m-Tc-DMSA (dimercaptosuccinic acid) and 99m-Tc-glucoheptonate; both accumulate primarily in the renal cortex and fall into a third category.

131/123-I-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 131-I label, once used for probe renography, yields very low-quality images with a high radiation dose and is no longer used.

99m-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, resulting in a lower extraction fraction. (Muller-Suur, 1989). 99m-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) (Bubeck B, et al, 1987) to replace the term ERPF.

99m-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 (Hauser W. et al 1970). There is about 5-10% protein bound DTPA in the plasma after one hour. DTPA labelled with 99m-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 (Stacy BD 1966, Chantler, 1972). It is not licensed in the US and is not suitable for imaging.

99m-Tc-DMSA (dimercaptosuccinic acid) (Lin TH, et al 1974) and 99m-Tc-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 detect a renal mass or defects in the renal parenchyma. These agents are also called renal cortical agents. 99m-Tc-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 in the kidney, the radiation dose of DMSA is significant and the administered dose should be chosen with that in mind.

VIII. 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.

a. Patient preparation: good hydration before and after radiopharmaceutical administration is essential. The patient should void before the beginning of the scan.
b. 99m-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.
c. Radiation burden: less than 1mSv with the activities below 100MBq. (ICRP 80, 1998; Stabin, 1992). Specific information is detailed in Tables 1 and 2.
d. 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).
e. Timing after injection and scan framing: a commonly used technique involves dynamic acquisition of 1-2 second images for 1-2 min. ("vascular" phase), starting immediately after radiopharmaceutical administration. It is followed by 10-15 second images for about 5 min. (functional uptake cortical transit), and then 20-30 sec. 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..
f. Patient Positioning: supine position; be careful to reduce motion. In patients who cannot lie flat it is possible to perform the exam seated with the back on gamma-camera detector.
g. Technical Parameters: Dynamic image acquisition
h. Collimator: Low Energy – High resolution or General purpose, according to availability
i. Minimum Matrix: 64x64 or 128 x128 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 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 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 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 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. If stopping the drugs is not possible, the study may still be performed. (Fommei, 1993) but the sensitivity is decreased. See the SNMMI guideline on this subject.

Static Renal Scan (Renal Cortical scintigraphy)

a. Radiopharmaceutical: 99m-Tc-DMSA provides the best images. Glucoheptonate may also be used.
b. Adult activity: 111 MBq
c. Radiation burden: approximately 1mSv (ICRP 80, 1998).
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 hours after radiopharmaceutical administration. In the presence of poor renal function late images (up to 20 hours) are helpful.
g. Patient Positioning: supine position; be careful with patient comfort to reduce motion.
h. Technical Parameters: Static image acquisition
i. Collimator: Low energy high resolution (LEHR), Low energy ultra-high resolution (LEUHR), or pinhole collimator
j. Minimum Matrix: 128x128 or 256x256 pixel with magnification (zoom) set to yield a preferred pixel size of 2 – 4 mm.
k. Total counts/ Time per view: At least 200000 total counts must be acquired or use fixed time of 5-10 minutes/ per view. If a pinhole collimator is being used, 100000 to 150000 total counts or 10 minutes should be acquired per view.
l. Views: Posterior and 30°-35° posterior oblique views. 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 on its usefulness (Piepsz, 2001).
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.

IX. 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 [Piepsz, 1990; Lythgoe, 1999; Caglar, 2008; Lezaic, 2008].

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 seconds for 99m-Tc-MAG3 or EC, 120-180 seconds for 99m-Tc-DTPA
There are two generally accepted 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 developed by Weslowskiusing liver activity to help with the normalization but it has not yet been confirmed fully (Blaufox 2016)

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 the 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)

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 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 (Delpassand, 2000)

Total (absolute) renal function

Total renal function (GFR and ERPF) assessment may be performed using radionuclides. This is a non-invasive and reproducible methodology (Blaufox 1996). Several methods have been introduced for this purpose (Schlegel, 1976, Tauxe, 1982, Gates, 1982, Bubeck, 1987, Taylor, 1995, Piepsz 2001, Itoh, 2003).
A comprehensive analysis is beyond the purposes of this guideline.

X. INTERPRETATION

Interpretation of the scan is highly dependent on the radiopharmaceutical used for imaging. The most frequently used compounds at present are 99m-Tc-MAG3 and 99m-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-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-Tc-MAG3 is preferred over 99m-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 decrease 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.

XI. SPECIAL CONSIDERATIONS FOR CHILDREN

See Pediatric guidelines

XII. 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 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 diuretic, angiotensin-converting enzyme inhibitor or angiotensin-receptor blocker, calcium blocker, 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 nephro-urologic imaging procedures (CT, US, 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 IV bolus injection.
c. Indicate other drugs used, such as furosemide 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) regions of interest (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, 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/sec and 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

XIII. EQUIPMENT SPECIFICATIONS

Gamma camera quality control must follow national rules or 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.

XIV. QUALITY CONTROL AND IMPROVEMENT

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

- motion
-sufficient number of counts
- extravasation
- appearance of activity in the heart ROI
- position of the patient
- position of the examined organs in the FOV

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 [Gordon 2011]. 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 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 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 [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.

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 [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 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 is extravagated
- 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

XV. RADIATION SAFETY IN IMAGING

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

	Administered activities						Largest radiation dose			Effective dose	
Radiopharmaceutical	MBq min		MBq max	mCi min		mCi max	Organ	mGy/MBq	rad/mCi	mSv/MBq	rem/mCi
^{51}Cr EDTA*	3.7	-	3.7	0.1	-	0.1	Bladder	0.024	0.0895	0.0020	0.008
^{123}I hippuran†	3.7	-	14.8	0.1	-	0.4	Bladder	0.19	0.71	0.0120	0.045
^{131}I hippuran†	1.295	-	1.295	0.035	-	0.035	Bladder	0.92	3.43	0.0520	0.196
^{99m}Tc DMSA*	74	-	222	2.0	-	6.0	Kidney	0.18	0.67	0.0088	0.033
^{99m}Tc DTPA*	185	-	370	5.0	-	10.0	Bladder	0.062	0.23	0.0049	0.018
^{99m}Tc EC*	185	-	370	5.0	-	10.0	Bladder	0.095	0.35	0.0063	0.024

^{99m}Tc glucoheptonate[#]	370	-	555	10.0	-	15.0	Bladder	0.056	0.21	0.0090	0.034
^{99m}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
^{51}Cr EDTA[*]	3.4×10^{-3}	2.6×10^{-3}	1.3×10^{-3}	1.2×10^{-3}
^{123}I Hippuran[†]	3.1×10^{-2}	2.4×10^{-2}	8.4×10^{-3}	7.9×10^{-3}
^{131}I Hippuran[†]	6.4×10^{-2}	5.0×10^{-2}	1.9×10^{-2}	1.8×10^{-2}
^{99m}Tc DMSA[†]	5.1×10^{-3}	4.7×10^{-3}	4.0×10^{-3}	3.4×10^{-3}
^{99m}Tc DTPA[†]	1.2×10^{-2}	8.7×10^{-3}	4.1×10^{-3}	4.7×10^{-3}
^{99m}Tc EC[*]	1.3×10^{-2}	9.7×10^{-3}	4.0×10^{-3}	3.8×10^{-3}
^{99m}Tc Glucoheptonate[†]	1.2×10^{-2}	1.1×10^{-2}	5.3×10^{-3}	4.6×10^{-3}
^{99m}Tc MAG3[†]	1.8×10^{-2}	1.4×10^{-2}	5.5×10^{-3}	5.2×10^{-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

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XVIII. APPROVAL

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