

Dynamic Renal Radionuclide Studies (Renography) Clinical Guidelines

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Purpose

These guidelines must be read in conjunction with the BNMS Generic Guidelines.

The purpose of this guideline is to assist specialists in Nuclear Medicine and Radionuclide Radiology in recommending, performing, interpreting and reporting the results of dynamic renal radionuclide studies. This guideline will assist individual departments in the development and formulation of their own local protocols.

These guidelines apply to studies on adults. For specific guidance for paediatric studies see the EANM guidelines for standard and diuretic renogram in children [1]

Background

The use of tracers which are taken up and excreted by the kidney allows the estimation of renal perfusion, divided function, kidney drainage and assessment of the lower urinary tract. The radiopharmaceutical is administered intravenously to the patient whilst they are in front of the gamma camera. A dynamic study is performed for between 20 and 40 minutes showing uptake of tracer into the kidneys and elimination into the bladder. The activity-time curves generated from this dynamic study are known as the renogram. The renogram can be used to assess renal function and drainage. This can be supplemented by additional static images of kidneys and bladder after the end of the dynamic study.

If outflow obstruction is suspected the study may be augmented by administration of a diuretic.

If it is required to assess the relative perfusion of the kidneys a first pass blood flow phase may be incorporated during the first minute of the dynamic study.

Common Indications

1. Assessment of renal perfusion.
2. Evaluation of divided renal function [2].
3. Assessment of possible obstruction [3].
4. Assessment of bladder function.
5. Post surgical evaluation of a previously obstructed system.
6. Evaluation of possible renovascular disease using Captopril (not covered in this guideline – see reference 4).
7. Follow-up of vesico-ureteric reflux by indirect micturating cystogram (not covered in this guideline).
8. Assessment of renal transplants (not covered in this guideline – see reference 5).

Contra-indications

1. Absolute
None
2. Relative
Recent use of radiographic contrast media.

Procedure

1. Patient preparation
 - 1.1 Before sending the patient instructions, the request form should be vetted in order to decide whether a diuretic stress or other intervention is required or appropriate. It may also be necessary to make arrangements for bladder catheterization if the patient is known to have bladder outflow problems and there is a question about upper tract obstruction.
 - 1.2 The patient should be well hydrated prior to the study. For adults, 300-500 ml of clear fluids should be taken in the hour prior to the study (unless clinically contra-indicated). Rarely, intravenous hydration with 10-15 ml/kg of normal saline may be needed.
 - 1.3 All medication being taken by the patient should be recorded (especially ACE inhibitors, All inhibitors and NSAIDs) and a record of any recent contrast study.
2. Injection technique.
 - 2.1 For first pass studies a good flushed bolus injection is required. This may require prior cannulation.
 - 2.2 If a first pass study is not needed then a single clean injection is all that is required. If this is given through a cannula or butterfly then this should be flushed immediately
3. Special precautions
None.

Radiopharmaceutical

1. ^{99m}Tc MAG3 (tiatide)¹ is the most widely used agent for renography. It is cleared by a combination of glomerular filtration and tubular secretion and so has good renal uptake. It is the agent of choice in children and in patients with impaired renal function. The ARSAC diagnostic reference level for adults is 100 MBq (or 200 MBq if first pass blood flow imaging is being performed) [6]. For children administered activity should be scaled according to body surface area.
2. ^{99m}Tc DTPA (pentatate)² is also widely used for renography. It is cleared only by glomerular filtration, and so can also be used for measurement of GFR. However the renal uptake is less than MAG3 and so non-renal background is more significant in patients with poor renal function. The ARSAC diagnostic reference level is 300 MBq (or 800 MBq if first pass blood flow imaging is being performed) [6].

¹ In 1995 the UK Government agreed to abide by a European directive with the objective of ensuring consistency of the names of medicinal products used throughout the European Union. This Law requires the use of the recommended International Non-propriety Name (INN) which will therefore replace the British Approved Name (BAN). BNMS propose to gradually introduce this terminology in all published guidelines. Therefore the BAN of MAG3 will be replaced by the INN of tiatide.

² The BAN of DTPA will be replaced by the INN of pentetate.

3. ^{99m}Tc MDP (medronate)³ is normally used for bone scintigraphy. It is also cleared by glomerular filtration, and so if a patient needs both bone imaging and a renogram, then both studies may be obtained with one dose of activity. However the parenchyma is not cleared quite as quickly as either of the standard renography tracers. The ARSAC diagnostic reference level is 600 MBq [6].

Image Acquisition

2. Energy window
The camera should be peaked on 140 keV, with a $\pm 10\%$ window.
3. Collimator
A low energy general purpose (LEGP) or low energy high sensitivity (LEHS) collimator is preferred. High resolution collimators are not recommended [2] as the purpose of the study is to quantify activity in kidneys and bladder rather than to obtain detailed images.
3. Patient position
 - 3.1 Images are usually obtained from the posterior position, but if there is a pelvic kidney this is best assessed with an anterior position of the camera.
 - 3.2 If a dual headed gamma camera is used both posterior and anterior views may be obtained simultaneously. Though both kidneys must be in the field of view.
 - 3.3 The patient should be made comfortable lying in a supine position or erect seated in a suitable imaging chair. If a chair is used it must offer sufficient support to prevent the patient from moving during the study. The supine position minimises differences in kidney depth but the seated position gives a better indication of drainage in some cases.[2, 3].
4. Views acquired.
 - 4.1 The patient should empty their bladder prior to the study. The time of this should be recorded so that the urine flow rate can be calculated.
 - 4.2 The dynamic renogram study is then performed. The field of view must include the kidneys and sufficient area above the kidneys for background definition. If deconvolution is to be carried out then the heart must be in the field of view. If the Patlak/Rutland plot is to be used then either the heart or spleen must be in the field of view. If possible the bladder should also be in the field of view.
 - 4.3 If the renogram was acquired in a supine position and the kidneys have not fully drained, then after the dynamic acquisition has finished an erect posterior image should then be acquired for 1 minute to include the kidneys and bladder [7].

³ The BAN of MDP will be replaced by the INN of medronate.

- 4.4 The patient should then empty their bladder again. The volume of urine passed and the time should be recorded if urine flow is to be calculated.
 - 4.5 A repeat erect post-micturition image is then acquired for 1 minute to include the kidneys and bladder [7].
 - 4.6 If the patient is catheterised, but the tube is not clamped, images should also be recorded of the catheter bag.
 - 4.7 If the patient has a urinary conduit then images should be obtained before and after emptying of the drainage bag.
If the kidneys have not drained a delayed image may be helpful.
If a urinary leak is suspected, delayed imaging up to 2 hours may be helpful.
5. Computer acquisition.
- 5.1 The images should be recorded with a 64x64 or 128x128 matrix. For paediatric studies a zoom may be applied.
 - 5.2 For general renography a 20-second frame rate is adequate [2]. If deconvolution analysis of transit times is being performed, then a 10-second frame rate is required [8]. For first-pass studies, 1 frame/second is required for the first 30 to 60 seconds but then the frame rate can drop to 10 or 20 seconds for the remainder of the study.
 - 5.3 The duration of the dynamic study is normally 30 minutes (minimum 20 minutes, maximum 40 minutes) [2]. If a diuretic is being administered during the study, then the dynamic acquisition should continue for a further 15-minute after the diuretic [3].
 - 5.4 If all images are acquired at the same zoom, matrix size, and frame time, then comparison of images from different stages of the study is simplified.

Interventions

6. Diuretic
- 1.1 If one or both kidneys have not emptied satisfactorily during the first 20 minutes (as assessed from the acquiring image or from "real-time" curves if available), then frusemide (furosemide)⁴ may be given as a diuretic 20 minutes into the study (this is known as "F+20"). However, if the kidney has already drained by this time there is no point in giving frusemide because there will be little activity left to demonstrate a response. The usual dose of frusemide is 0.5 mg/kg (up to 40 mg for an adult) administered intravenously as a slow bolus [9].
 - 1.2 If it is known from the request that there is a clinical suspicion of obstruction, or a previous renogram has shown an equivocal response to frusemide, then a maximum diuretic response can be obtained by the administration of frusemide 15 minutes before the start of the study ("F-15") [3]. However this means that there

⁴ The BAN of frusemide will be replaced by the INN of furosemide

is no opportunity to assess kidney drainage under normal flow rates.

- 1.3 If venous access is difficult, there is some evidence to suggest that frusemide given immediately before the radioactive tracer through the same cannula ("F+0") is almost as effective. This timing is commonly used in paediatrics. This may also be needed in patients with surgically produced bladders post cystectomy as "bladder" volumes can be very small and overflow can occur with a F-15 study.
- 1.4 It can be helpful to document the response to the diuretic by measuring the urine flow rate. A flow of more than 10 ml/min indicates that frusemide has been effective.

2. ACE-Inhibitor

This protocol does not cover the use of ACEI-stress studies (see reference 4).

Data Analysis

1. The dynamic data should be reviewed to check that there has been no patient movement. If necessary small amounts of movement may be corrected by shifting the relevant frames.
2. Regions of interest should be drawn over each kidney (to include the renal pelvis), background areas (using perirenal areas around the borders of each kidney, taking care not to cut across the renal pelvis or ureter) and over the bladder.
3. The regions of interest should be reviewed on a cine display of the dynamic study to ensure that they cover the required area throughout the study
4. Background-corrected activity-time curves should be derived from each kidney.
5. The divided function should be calculated. This may be most simply obtained from the integral of these curves, starting not before 60 seconds and ending before 2 min 30 secs [2].
6. A more reproducible and robust divided function may be obtained from a Rutland/Patlak plot. This is recommended particularly if ^{99m}Tc DTPA is used or if renal function is poor [2]. This method requires definition of an additional blood region of interest over the heart or the spleen to assess vascular background and the perirenal background regions may be replaced by a tissue background region below the kidney [2].
7. The output efficiency is a useful method of quantifying renal clearance in possible obstruction [10].
8. Regions should also be drawn on the pre-and post-micturition images and any late images to compare kidney activity with the activity at the end of the renogram
9. The patient's urine output rate can be obtained from the volume of urine passed and the time between voids.
10. The residual volume may be estimated from the counts in a bladder region of interest on the pre-micturition and post-micturition images and a knowledge of the urine volume passed.

Hard copy and PACS output

1. Output must be labelled with the patient's name, ID number, date of study, radiopharmaceutical, the timing of any diuretic given and urine flow rate if calculated.
2. Images should be generated from 0-30 or 0-40 seconds (to show summed perfusion), at about 2-3 minutes (to show parenchymal uptake pattern and then at intervals to show the different phases of the study [2]. The images should all be displayed with the same absolute maximum in order to allow visual assessment of parenchymal clearance. The pre- and post-micturition images should also be recorded and displayed with the same maximum. Images must be labelled with the side (L/R) clearly identified.
3. Curves should be recorded and labelled so that there is clear indication of which curve corresponds to which kidney. The ROIs from which they are produced should also be recorded [2].
4. The divided function must be recorded and the method used for its calculation should be indicated.
5. If the output efficiency has been calculated, the curves and output should be recorded.
6. To allow comparison between studies, it is helpful to display the curves either as a percentage of the injected dose, or normalised to a standard activity and patient size. The scale used should be consistent from one study to another [7].

Interpretation and report

1. Any delay in perfusion of the kidneys may be assessed from the summed first pass image.
2. The relative perfusion of the kidneys may be assessed from the ratio of the up-slopes of the first-pass curves.
3. The pattern of parenchymal uptake at two minutes may be used as a good indicator of morphology, size, and possible gross scarring.
4. The parenchymal clearance is assessed from serial images, provided that there is an adequate diuresis rate.
5. Possible obstruction is assessed from the diuretic response provided there is adequate hydration.
6. Obstruction should only be reported if the renogram curve continues to rise despite hydration and administration of a diuretic.
7. Poor or minimal drainage from either kidney may be clinically important and should be reported even if the kidney does not meet the criteria for obstruction.
8. The effect of gravity and bladder emptying on kidney drainage is assessed by comparison of the final dynamic image with the images pre- and post-micturition.
9. The adequacy of bladder emptying can be assessed from the images pre- and post-micturition, together with the calculated residual bladder volume.

Pitfalls

1. Inadequate hydration can produce a renogram pattern that mimics obstruction
2. Extravasation and/or poor bolus injection.
3. Vasovagal attack or hypotension. This is often not appreciated clinically, particularly if the study is acquired supine.
4. NSAID's eg. Diclofenac.
5. Back pressure from an overfilled bladder may prevent kidney drainage. In such cases delayed post-micturition images (eg 1 hour after injection) can be valuable.
6. ^{99m}Tc MAG3 cannot separate ATN from obstruction in acute renal failure, whereas ^{99m}Tc DTPA gives very different appearances.
7. A poorly functioning kidney may not give a normal diuretic response because frusemide relies on tubular secretion to reach its site of action.
8. In cases of bilateral obstruction the urine flow rate cannot be used as an indication of the effectiveness of frusemide.

Controversies

1. Definition of obstruction.
2. Timing of diuretic administration
3. Value of deconvolution analysis to determine mean transit time [8]
4. Attempts to measure absolute renal function from the gamma camera study
5. Methods of correcting for kidney depth.

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These guidelines do not constitute a formal protocol but highlight the aspects of a study where variation in practice may significantly affect the quality of outcome of the study.

