

REVIEWS

Radionuclide Imaging. An Update on the Use of Dynamic Renal Scintigraphy

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Abstract

Renal scintigraphy is a nuclear medicine technique that uses medical radioactive isotopes for the evaluation of the renal function. Functional data complete clinical and anatomical data obtained through other imaging techniques and can assist the clinician in the diagnostic and management of various renal disorders. Radionuclide imaging provides important functional informations which complement anatomic evaluation performed by morphologic techniques – intravenous urography, ultrasound imaging, computerized tomography (CT) or magnetic resonance imaging (MRI). It also have the advantage of evaluating the functional status of each kidney – information that cannot be obtained through biochemical assessment of serum creatinine and blood urea nitrogen (BUN). The current work will focus on the dynamic scintigraphy, protocol of examination, quantitative parameters and current indications, with emphasize on the obstructive renal disease.

Keywords: radionuclide imaging, renal dynamic scintigraphy, radioisotopes, renal function, obstructive renal disease

Rezumat

Scintigrafia renală este o tehnică de medicină nucleară care utilizează izotopi radioactivi pentru evaluarea funcției renale. Informațiile funcționale obținute prin tehnicile de medicină nucleară completează tabloul clinic și informațiile anatomice obținute prin alte tehnici imagistice și pot ajuta clinicianul în diagnosticul și gestionarea stărilor patologice din sfera aparatului urinar. Tehnicile de diagnostic radioizotopic oferă date funcționale importante complementare datelor obținute prin tehnici morfologice - urografie intravenoasă, ecografie, tomografie computerizată (CT) sau imagistică prin rezonanță magnetică (IRM). Medicina nucleară are totodată avantajul de a evalua starea funcțională a fiecărui rinichi - informații care nu pot fi obținute prin dozarea creatininei serice și a ureei. Lucrarea actuală se va concentra asupra scintigrafiei renale dinamice, cu prezentarea radiotrasorilor utilizați, a protocoalelor de examinare, parametrilor obținuți prin analiza cantitativă și a indicațiilor actuale, cu accent pe boala renală obstructivă.

Cuvinte cheie: imagistica radionuclidică, scintigrafie renală dinamică, radioizotopi, funcție renală, boala obstructivă renală

INTRODUCTION

Renal scintigraphy is a nuclear medicine technique that uses medical radioactive isotopes for the evaluation of the renal function. Functional data complete clinical and anatomical data obtained through other imaging

techniques and can assist the clinician in the diagnostic and management of various renal disorders.

The most widely used radioactive isotope for medical imaging is Technetium-99m. In renal scintigraphy ^{99m}Tc is coupled to a substance that is eliminated predominantly by glomerular filtration (DTPA)

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or tubular excretion (MAG3) or which is attached to tubular proteins (DMSA). DTPA and MAG3 allow a dynamic study which result in the generation of a nephrographic curve for each kidney and the calculation of clearance parameters - ie glomerular filtration rate (GFR) or the effective renal plasma flow (ERPF), respectively.

Usual biochemical tests as determination of serum creatinine and blood urea nitrogen (BUN) – are both useful tools for the evaluation of total renal function. However, these blood parameters cannot evaluate each kidney individually. Moreover, relevant changes in blood levels of serum creatinine or BUN arise late in the evolution of renal disease, usually when renal function is already severely impaired.

Radionuclide imaging is functional imaging. It usually complete the anatomic evaluation performed by morphologic techniques – intravenous urography, ultrasound imaging, computerized tomography (CT) or magnetic resonance imaging (MRI).

PURPOSE

The purpose of this paper is to review the literature and present a useful but definitely underutilized imaging technique - dynamic renal scintigraphy. This paper is aimed to allow a better understanding of clinical applications of dynamic renal scintigraphy with emphasis on obstructive renal disease, to realize an overview of technique protocol, interpretation and clinical use.

MATERIAL AND METHOD

Indications

Current indications of renal scintigraphy are listed in table 1.

Radiopharmaceuticals

There are several radiopharmaceutical that can be used for the evaluation of renal function. Two radiopharmaceuticals are currently available worldwide for performing a dynamic renal imaging study: Tc-99m-diethylene triaminepentaaceticacid (DTPA) and Tc-99m- mercaptoacetyltriglycine (MAG3). Tc-99m- dimercaptosuccinic acid (DMSA) is a cortical agent used for the so-called static radionuclide imaging. There are also radiopharmaceuticals used in the non-imaging assesment of GFR: 51Cr-Ethylenediaminetetraacetic acid (EDTA) and 125I-Iothalamate (Glomerular Filtration). These radiopharmaceuticals allows GFR assesment through a method that uses plasma samples.

Tc-99m-diethylene triaminepentaaceticacid (DTPA) is mainly eliminated by glomerular filtration. It can be therefore used for a very accurate measurement of the filtration rate. The extraction fraction is about 20% in normal patients^{2,3}. In patient with severely reduced renal function this extraction fraction can result in a lower sensitivity of the study⁴.

Tc-99m- mercaptoacetyltriglycine (MAG3) is cleared mainly by tubular secretion and has a higher extraction fraction than DTPA^{5,6}. For this reason this is the preferred radiopharmaceutical for renal scans in most of the nuclear medicine centers worldwide, especially those in the USA⁶. The 99mTc-MAG3 clearance is described as the tubular extraction rate and can be considered as independent measure of renal function^{3,7}.

Tc-99m- dimercaptosuccinic acid (DMSA) is used for renal static studies with assesment of relative function in pyelonephritis and renal scar⁸. DMSA is bound to proximal tubular cellular proteins. Many centers uses this radiotracer for pediatric evaluation of renal pathology.

Table 1. Current indications of renal scintigraphy - adapted from Harvey A Ziessman et al. Nuclear Medicine: The Requisites, 4th ed):¹

1	Blood flow abnormalities
2	Function quantification - Differential function, Glomerular filtration rate (GFR), effective renal plasma flow (EPRF)
3	Differentiation between a mass lesion and a column of Bertin
4	In infants with abnormalities of the urinary tract to study the urinary flow
5	Obstruction: ureteropelvic junction, ureteral obstruction
6	Pyelonephritis
7	Renal failure: acute and chronic
8	Renal artery stenosis with/without renovascular hypertension
9	Renal vein thrombosis
10	Renal transplant evaluation – transplant rejection, transplant anastomosis assesment

Due to the fact that in Romania the only available radiotracer at the time of submitting this paper is ^{99m}Tc -DTPA – the current work will focus on the dynamic DTPA studies, protocol of examination and current indications, with emphasize on the obstructive renal disease.

Patient preparation

Patient should drink 0.5 l of water 30 minutes before the examination - because some renal functional parameters may change in the presence of dehydration. Good hydration is also important in minimizing the absorbed radiation dose of the bladder.

According to some researchers medication with anti-inflammatory drugs should be discontinued prior to procedure because they have the potential of influencing parameters of the renogram⁹. If the study is performed for suspected renovascular hypertension, special preparation is required, with good hydration, use of diuretic medication, discontinuing angiotensin-converting enzyme inhibitors prior to the basal study¹⁰.

Protocol of investigation

The radiopharmaceutical is administered intravenously, with the patient already in the supine positioned on the gamma camera table. Dynamic acquisition of images begins immediately. The administered dose is 10–15 mCi (370 – 555 MBq). This dosage is required for obtaining enough counts for calculating flow parameters. Many authors shown that flow studies result in essential information in the evaluation of renal transplant^{11,12} but is of less importance in all other indications, including renovascular hypertension. Therefore according to some authors – an administered dose of 37 – 185 MBq is appropriate for the great majority of indications³.

The entire procedure takes 20-30 minutes. Acquisition is made with the dynamic protocol with serial images initially acquired rapidly at every 1-3s for the flow study, followed by sequential with 10s to 20s per frame for the renal function. Displayed images correspond to the radioactive bolus passing through aorta to renal arteries in the flow study, followed by the passage of the radioactivity through the kidneys.

RESULTS

After the acquisition image will be checked in order to assess if the examination was properly performed. After visual inspection region of interest (ROIs) will be placed over each kidney and time-activity curve will be generated (renogram). This represents a graphic illus-

tration of the uptake and excretion of the radiotracer through the kidney. Normal renogram (Figure 1) has 3 parts:

1. Initial rapid ascendant segment – due to the vascular supply to the kidney. This phase reflects the bolus of radioactivity that arrives via the renal artery to the kidney.
2. Ascendant segment corresponding to the accumulation of the tracer in the kidney up to a peak activity. This peak is the point at which the extraction and accumulation trend is reversed to the evacuation process. Two factors are currently influencing the rate at which the renogram rises over this ascendant segment: the blood concentration of tracer and function of the kidney (individual kidney GFR for ^{99m}Tc -DTPA)¹³.
3. Descendent segment - reflects the excretion of the radiotracer from the kidney. In this phase the gradient of the renogram depends on the rate at which the radiotracer is eliminated.

In obstructive renal disease the curve generated from the ROI placed on the affected kidney has a typical appearance - slow continuous accumulation of tracer in the collecting system, a slow increasing ascending curve with no downslope. In contrast, a normal kidney will show a good uptake and excretion, and a normal three part TAC^{14,15}.

Diuretic renography may be indicated in order to differentiate between obstructive and nonobstructed dilated urinary tract. The technique consists of the administration of a diuretic agent (furosemid) after the 20 min dynamic renal study and imaging 10 to 30 min more with the same dynamic protocol. If no obstructi-

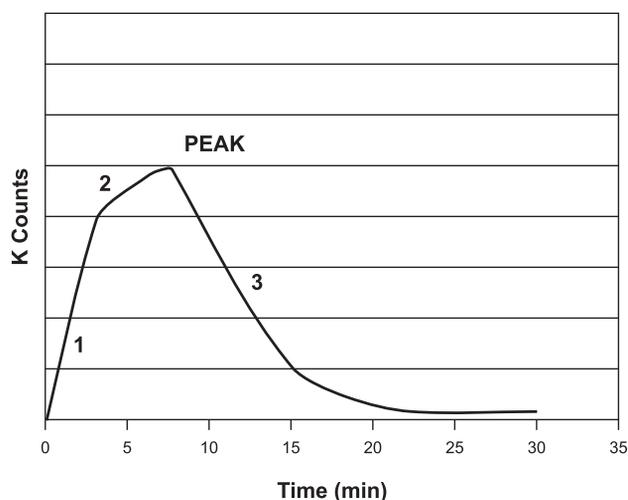


Figure 1. Time activity curve in a normal kidney (adapted from EANM: Dynamic renal imaging in obstructive renal pathology. A Technologist's Guide)¹⁵.

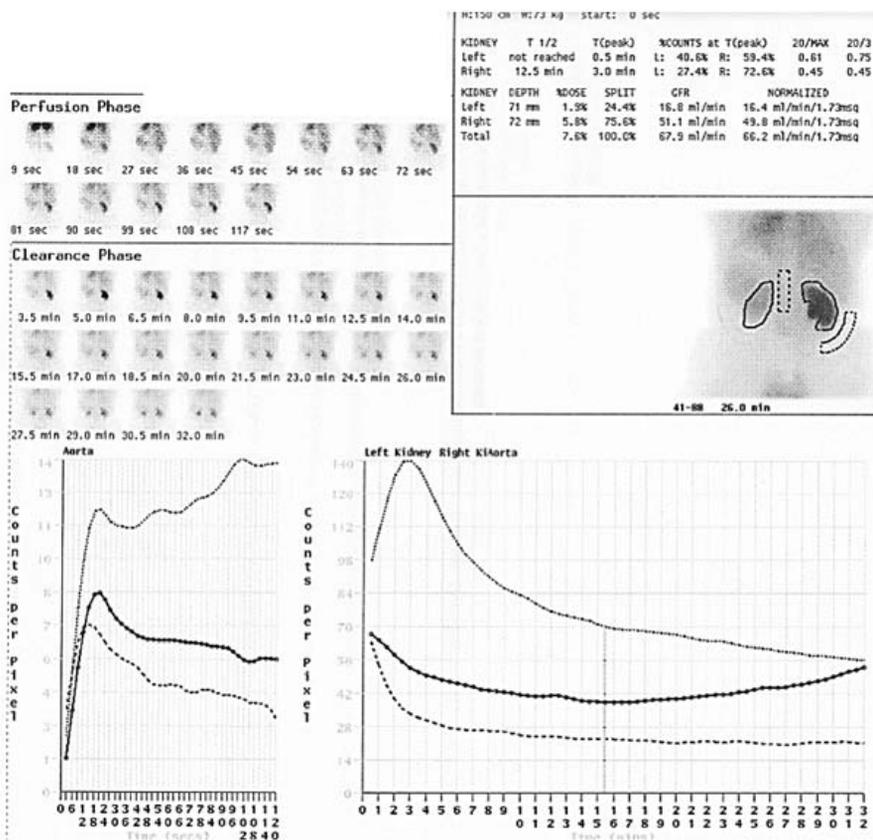


Figure 2. Right kidney with normal renogram. Left kidney obstruction with renogram showing ascendant excretory segment.

on is present – the renogram will show a rapid drainage of the radioactivity through the collecting system. If mechanical obstruction is present – the radiotracer will accumulate and excretion phase of the renogram will show ascendant slope^{10,15}.

Quantitative analyze

Processing of the renal dynamic scintigraphy usually result in some quantitative parameters and indices that will be reported. This ability to perform quantitation is one of the most important advantage of functional techniques, not only because it helps documenting some pathologic condition but also because it allows follow up.

Here are some quantitative parameters usually calculated during the dynamic renal scan:

Relative perfusion - this is the flow phase, which is important for the evaluation of renal number anomalies and renal transplant^{3,16} most radionuclide renal studies are conducted at institutions that perform fewer than 3 studies per week, and a large percentage of studies are interpreted by physicians with limited training in nuclear medicine. Ten panelists were asked to categorize specific reporting elements as essential, recommended, optional (without sufficient data to support a

higher ranking. It represents the transit of radioactive bolus through abdominal aorta to renal arteries. Asymmetries or delays in perfusion may suggest abnormal perfusion. Delay in renal visualization can sometimes suggest suboptimal injection technique.

Relative Function represents the relative uptake of the radiopharmaceutical and quantifies the differential renal function. This “split” or “differential” function is particularly useful because estimated GFR and/or serum creatinine may not identify unilateral lesions¹. In normal patients this split function ranges from 42% to 58%⁶.

T max (Time to peak) – time interval between injection and the peak of the renogram curve. Normal Tmax ranges from 3 min to 5 min for DTPA and MAG^{3,17,18}.

The T1/2 - time interval in which radioactivity in the kidney decreases 50% of the maximum value (T max). Normal T1/2 should be less than 20 min. T1/2 is of very important value in diuretic renography in suspected obstructive disease^{10,18}.

The 20-min/maximum count ratio represents the ratio between total kidney counts at 20 min to the total number of kidney counts at peak (maximum counts); it practically offer a measurement of parenchymal functi-

on and transit time; for normal subject and for MAG3 renogram - total 20 min/max count ratio is 0.19⁶; this parameter is useful in monitoring patients with suspected urinary tract obstruction and for detecting renovascular hypertension^{3,17,18}.

Clearance measurement – can be acquired using plasma samples or camera-based algorithms. Plasma sample techniques allows estimation of clearance from the dose injected and the measured radioactivity in a blood sample 45 min after injection^{1,14,19}.

This technique is reliable and accurate but requires experienced and properly trained operator and can be affected if there is no normal volume (ascites, large edemas, etc)³.

Camera based algorithms for DTPA and MAG3 are easy to perform, highly reproducible, do not require blood samples and can be used at the time of renal dynamic scan. At present software delivered with gamma camera equipments provide accurate estimation of GFR for DTPA (or clearance, ERPF for MAG3), with automatically correction for renal depth

or background corrections²⁰. Camera-based clearances are reproducible and superior to creatinine clearance for monitoring changes in renal function^{3,21}.

CONCLUSION

Renal radionuclide studies are reliable procedures that provide essential information about renal function, not available with other anatomical imaging technique. These informations have the ability to complete clinical and morphologic evaluation performed by other imaging modalities for an efficient diagnostic process. The possibility of quantification allows measurement of various parameters which can be useful not only in diagnostic but also for monitoring treatment response. Radionuclide techniques are definitely underutilized in Romania. Efforts should be made in order to increase logistic capacity at least at hospital level, in order to open the access to high quality diagnostic capabilities to a larger number of medical professionals and patients.

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