

ADDITIONAL VALUE OF SPECT/CT IMAGING
TO ^{99m}Tc -DTPA DYNAMIC RENAL SCINTIGRAPHY
IN THE DIAGNOSIS OF PATIENTS WITH DIFFERENT
NEPHRO-UROLOGICAL CONDITIONS

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Abstract

Dynamic renal scintigraphy with ^{99m}Tc Technetium diethylenetriaminepentaacetic acid (^{99m}Tc -DTPA) is a generally used imaging technique for evaluating renal function of patients with various nephro-urological conditions. However, the application of SPECT/CT is not regularly performed as a part of the study. The aim of the study was to evaluate the added value of SPECT/CT imaging to dynamic renal scintigraphy with ^{99m}Tc -DTPA. Thirty-eight patients – 23 females (60.5%) and 15 males (39.5%), aged 16–83 years (mean: 55.4, standard deviation: 18.76) underwent dynamic nephroscintigraphy with subsequent SPECT/CT. The CT scan was performed with a low dose protocol. A dose of 185 MBq (5 mCi) ^{99m}Tc -DTPA was administered intravenously. Our analysis demonstrated impaired relative renal function in various degrees of left kidney in 21 patients (55.3%) and of right kidney in 17 patients (44.7%). SPECT/CT imaging revealed the specific cause, responsible for the renal dysfunction in the cases. The hybrid imaging demonstrated calculosis in 11 patients, urological cancer in 6 patients, postoperative strictures of ureter in five patients, external compression of ureter from ovarian cyst in one patient and compression of ureter due to nephroptosis in one patient as a possible obstructive cause. In 14 patients congenital renal anomalies were the identified causes of impaired renal function – hypoplastic kidney in five patients, duplex kidney in three patients, multiple cortical cysts in three patients, aberrant vessel

obstructing the pyelo-ureteral segment in two patients and horseshoe kidney in one patient. The combination of conventional ^{99m}Tc -DTPA dynamic renal scintigraphy with subsequent SPECT/CT could provide not only functional but also anatomical information of the urinary tract, especially in the evaluation of obstructive uropathies and congenital renal abnormalities that can change the clinical management.

Key words: ^{99m}Tc -DTPA dynamic renal scintigraphy, SPECT/CT, uropathies, nephropathies

Introduction. Dynamic renal scintigraphy with ^{99m}Tc Technetium diethylene-triaminepentaacetic acid (^{99m}Tc -DTPA) is a widely used method for renal function evaluation of patients with different nephron-uroligical conditions – kidney anomalies, nephrocalculosis, obstructive uropathies before and after operation, nephrotoxicity, renal transplant, etc. [1].

Nephroscintigraphy is an indispensable imaging method in determining the degree of obstructive uropathy [2].

The study is evaluated in two ways – qualitative (visual) and quantitative, using different parameters, for example, relative renal function, which is an important indicator that is difficult to determine with other methods, $T_{\max}$ and $T_{1/2}$ [3, 4].

One of the main indications for conducting the study is the diagnosis of obstruction of the excretory system. Combining the dynamic renal scintigraphy with the 3D-SPECT/CT method would allow accurate localization of the pathological process (for example, in case of calculus or external compression of the ureter), increasing the informative value of the study and determining the accurate diagnosis. The method is suitable for determining the type of operation procedure needed and for monitoring treatment results. SPECT camera systems with built-in computed tomography (CT) provide the ability to integrate functional and anatomical imaging during a single examination, allowing a one-stop-shop evaluation for various diseases.

Dynamic renal scintigraphy with subsequent SPECT/CT examination is a diagnostic method possessing a number of advantages, including good technical reproducibility, low levels of radiation exposure, good tolerance of the examination by the patient and absence of allergic reactions and unwanted side effects [5].

The method could be used for morphological and functional evaluation of the kidneys in patients with an allergy to the contrast agents used in CT and MRI scans, or in patients with impaired renal function, where their nephrotoxic effect can lead to severe consequences [6].

However, the clinical application of consequent SPECT/CT examination after dynamic nephroscintigraphy is not routinely performed and is therefore a rarely discussed topic in the medical literature.

The aim of the study was to evaluate the added value of SPECT/CT imaging to dynamic renal scintigraphy with ^{99m}Tc -DTPA.

Materials and methods. A retrospective study was conducted between October 2018 and July 2023. A cohort of 38 patients – 23 women (60.5%) and 15 men (39.5%), aged 16 to 83 years (mean: 55.4, standard deviation: 18.76) underwent dynamic renal scintigraphy with consequent SPECT/CT examination. Written informed consent was obtained from each patient for the examination with ^{99m}Tc -DTPA and subsequent SPECT/CT scan in the lumbar region. Preparation of the patients included intake of approximately 500 ml of water 30 min before the examination and discontinuation of diuretics in each patient at least 24 h before the examination.

Patients were scanned in supine position. The dynamic study was performed after an intravenous bolus injection of 185 MBq (5 mCi) ^{99m}Tc -DTPA. The SPECT/CT scan protocol included 360° rotation mode with 64 projections, 25s/projection, matrix 256×256 , followed by a low-dose CT scan with the following parameters – voltage 130 kV, current magnitude 30–50 mA; slice thickness 3–5 mm.

Results. After analyzing the results of the dynamic nephroscintigraphy, impaired relative renal function was found in various degrees in 21 patients of the left kidney (55.3%) and in 17 of the right kidney (44.7%). Loss of function of one kidney was found in 16 patients (Fig. 1).

The subsequent SPECT/CT enabled the visualization of the cause for renal dysfunction in the analyzed 38 cases. The hybrid SPECT/CT images revealed obstructive uropathy caused by urolithiasis in 11 patients (29%), of them, unilateral involvement was found in 9 people (24%). In other two patients, there was a different degree of bilateral obstruction from calculi.

Staghorn calculi were found in two of the patients and the volume of the following operative interventions was planned based on the performed SPECT/CT study. This confirms the clinical usefulness of the method when a decision on the necessity and volume of the surgical intervention is made, determining the exact condition of the urinary system.

The second most frequently diagnosed cause of impaired renal function by SPECT/CT was urological cancer in six (16%) of all patients.

The third most common cause of renal dysfunction among the obstructive causes were postoperative strictures of ureter in five patients (13%).

In one patient external compression of ureter from ovarian cyst and compression of ureter due to nephroptosis in one patient were observed as a possible obstructive cause.

In 14 patients congenital renal anomalies were the identified causes of impaired renal function – hypoplastic kidney in five patients, duplex kidney in three patients (Fig. 2), multiple cortical cysts in three patients (Fig. 3), aberrant vessel obstructing the pyelo-ureteral segment in two patients and horseshoe kidney in one patient (Fig. 4).

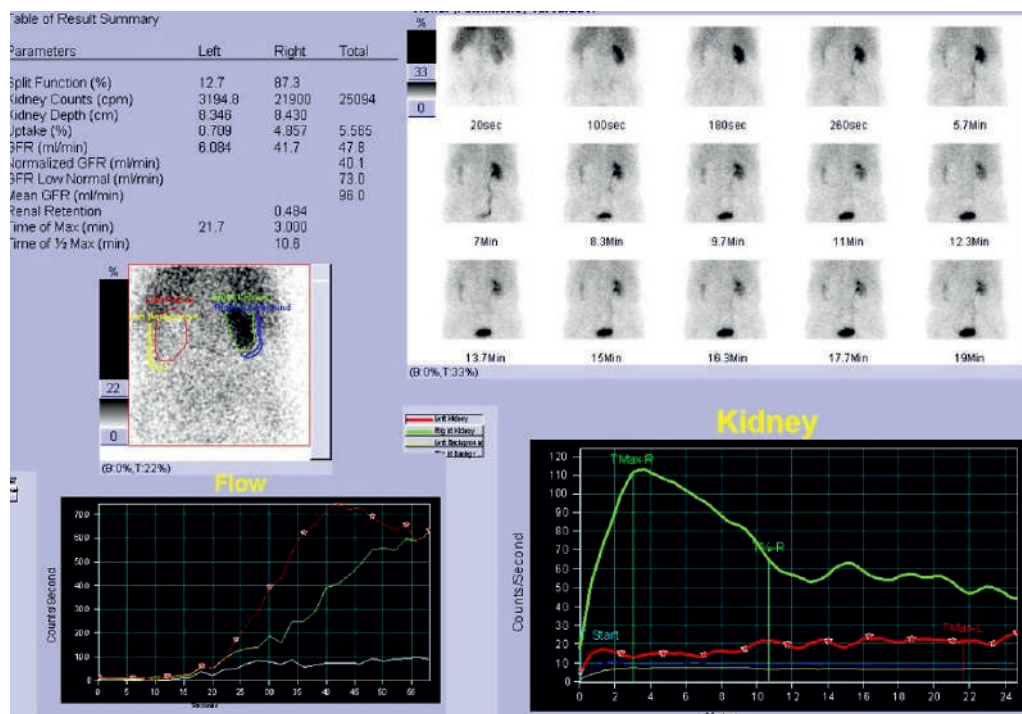


Fig. 1. Dynamic renal scintigraphy of a 75-year-old man. The right kidney is with preserved shape and size, with preserved secretory function, $T_{\max} = 3$ min (norm up to 6 min) and preserved excretory function, $T_{1/2} = 21.7$ min (norm up to 25 min) – the green nephrogram. The left kidney is with intensely reduced radiopharmaceutical fixation with a renal failure pattern nephrogram, without detecting $T_{\max}$ and $T_{1/2}$, (the red curve) – suggestive of loss of function of the left kidney. Relative function left kidney:right kidney is 12.7%:87.3%, respectively

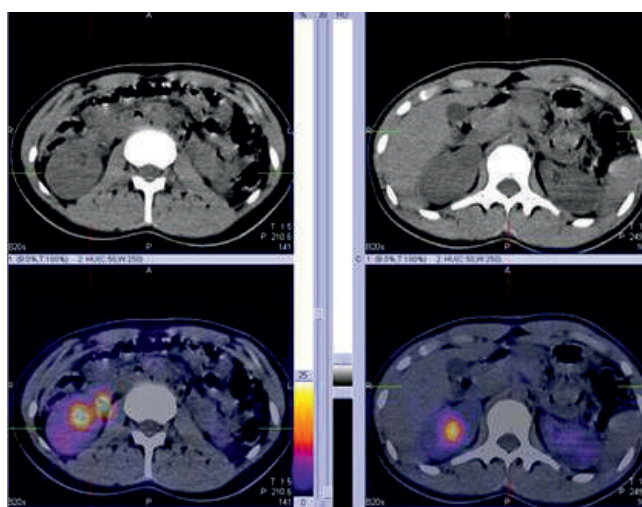


Fig. 2. Hybrid SPECT/CT imaging demonstrates a duplex kidney to the right with a common pyelon and ureter

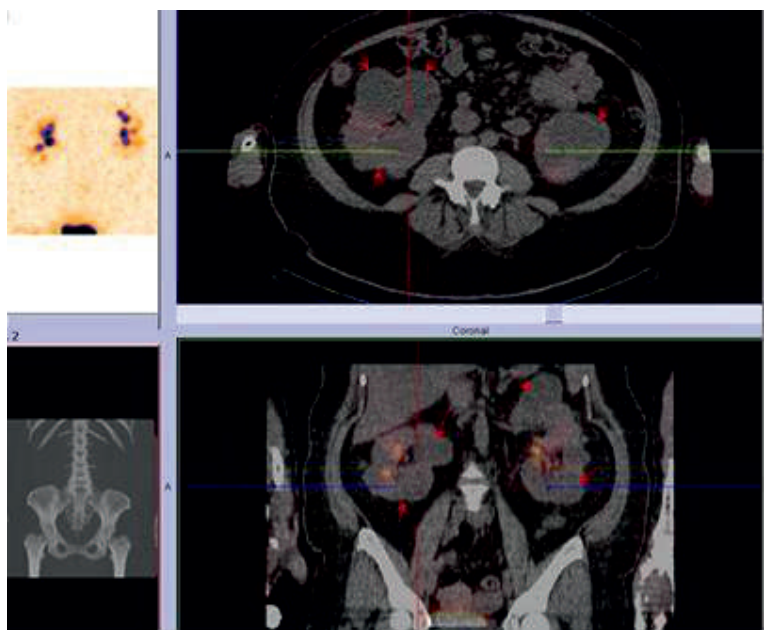


Fig. 3. Hybrid SPECT/CT images reveal multiple cortical cysts in both kidneys, leading to a general increase in their transverse and longitudinal dimensions

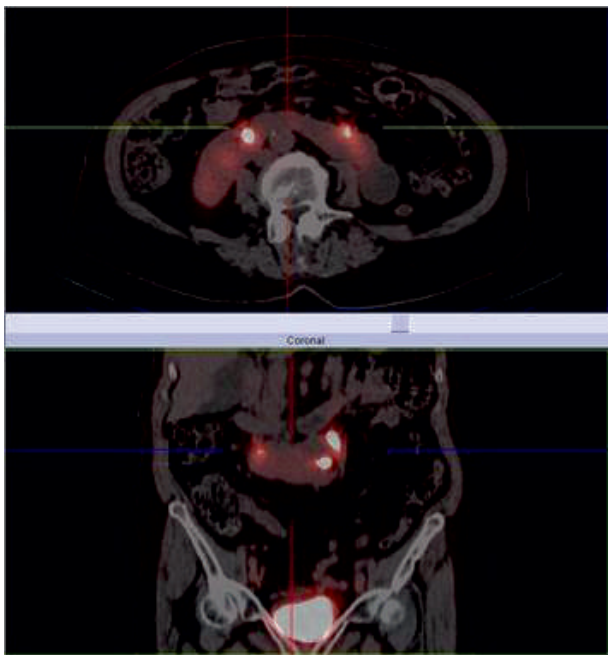


Fig. 4. SPECT/CT imaging reveals a congenital anomaly – a horseshoe kidney, with a fibrous bridge connecting the two lower poles of the kidneys. A cortical cyst of the left kidney is seen

The clinical application of dynamic renal scintigraphy and subsequent SPECT/CT scanning was also used for the follow-up of patients in whom renal dysfunction was already diagnosed, in order to assess and guide clinical management and following therapy. The provided information (physiological and dynamic) is suitable for determining the type of therapeutic approach – watchful waiting, conservative treatment, minimally invasive surgical methods of treatment (extracorporeal lithotripsy, ureterorenoscopy, percutaneous nephrolithotripsy) or radical surgical treatment in oncological patients.

Discussion. In order to accept the diagnosis loss of renal function, it is necessary to register a renogram, suggestive of nephrectomy, absent or weak accumulation of the radiopharmaceutical in the renal parenchyma, and relative function of the kidney below 15% [7].

Some authors consider values $< 10\%$ as an indication for nephrectomy [8]. However, in cases of relative renal function in the range 15–20%, recovery of renal function is rarely successful [9].

On the other hand, in cases of congenital hydronephrosis due to pyeloureteral stricture SINGH et al. [10] claim that when the relative renal function is $> 15\%$ pyeloplasty is the method of choice, for values below 5% nephrectomy is necessary, and for values in the range of 6–15% percutaneous nephrostomy placement is appropriate, but in the absence of improvement nephrectomy is required.

However, these percentages are relative and can sometimes be misleading. Results mimicking impaired kidney function when conducting dynamic renal scintigraphy can be obtained when the patient is poorly hydrated, in cases of extravasal injection, vessel collapse, non-obstructive dilatation of the pyelocalyx system, immature kidneys that lead to delayed accumulation and excretion of the radiopharmaceutical.

A subsequent SPECT/CT scan can help in the differentiation of morphologic causes (obstruction, nonobstructive dilatation of the pyelocalyx system, and immature kidney, leading to retention) and therefore increases the diagnostic accuracy of the study.

There is scarce amount of data in the medical literature for the application of ^{99m}Tc -DTPA dynamic renal scintigraphy combined with SPECT/CT in patients with urological diseases.

Ji et al. [11] pointed that the combination of ^{99m}Tc -DTPA dynamic renal scintigraphy and subsequent SPECT/CT imaging could be used in the clinical examination of patients with obstructive uropathies, thus obtaining functional and morphological information providing assurance in the clinical management of patients with obstructive renal diseases.

In a publication MIYAZAKI et al. [12] proved that ^{99m}Tc -DTPA SPECT and CT volumetry for measuring relative renal function had a superiority compared to planar ^{99m}Tc -DTPA imaging, indicating the utility of CT data in the evaluation of relative renal function [12].

A similar publication on the application of dynamic renal scintigraphy with SPECT/CT was published by JUNG et al. [13], reporting a case of urinoma in which other imaging modalities (ultrasound, intravenous pyelography, and planar renal scintigraphy) were inconclusive of the diagnosis. SPECT/CT was the method that helped in finding the correct diagnosis, due to the fact that imaging methods such as CT and ultrasound have a limited role in revealing the origin of fluid collections in the abdominal cavity and pelvis. Intravenous pyelography is a relatively insensitive method for diagnosing urine leakage. Normal results are found in more than 30% of cases with significant renal trauma and urine leakage [14].

Although dynamic renal scintigraphy is used to detect urine leakage and urinomas, planar examination may show inconclusive results, where SPECT/CT may increase sensitivity by accurately localizing the collection and the site of leakage [15].

Conclusion. The application of the SPECT-CT method significantly increases the diagnostic accuracy of dynamic nephroscintigraphy, which can be applied practically in detecting morphological causes, determining the presence and degree of renal or ureteral obstruction, as well as following up of patients with kidney disorders in order to assess and guide clinical management and following therapy. The combination of conventional dynamic renal scintigraphy with SPECT/CT provides functional and anatomical information about the kidneys and ureters in the assessment of obstructive uropathies, congenital renal conditions, and urothelial cancer, allowing a one-stop-shop evaluation of various nephro-urological diseases.

REFERENCES

- [1] BANKER H., E. G. SHEFFIELD, H. L. COHEN (2023) Nuclear Renal Scan, Treasure Island (FL), StatPearls Publishing.
- [2] DURAND E., A. PRIGENT (2002) The basics of renal imaging and function studies, *Q. J. Nucl. Med.*, **46**, 249–267.
- [3] YALÇIN H., A. OZEN, E. C. GÜNAY et al. (2011) Can Tc 99m DTPA be used in adult patients in evaluation of relative renal function measurement as the reference Tc 99m DMSA method?, *Mol. Imaging Radionucl. Ther.*, **20**(1), 14–18.
- [4] TAYLOR A. T., D. C. BRANDON, D. DE PALMA et al. (2018) SNMMI Procedure Standard/EANM Practice Guideline for Diuretic Renal Scintigraphy in Adults with Suspected Upper Urinary Tract Obstruction 1.0, *Semin. Nucl. Med.*, **48**, 377–390.
- [5] PENCHARZ D., N. HERAGHTY, A. M. PETERS (2022) Gamma camera imaging of the kidney, *Nuclear Medicine and Molecular Imaging*, Elsevier, 253–269.
- [6] MAZRANI W., K. MCHUGH, P. J. MARSDEN (2007) The radiation burden of radiological investigations, *Arch. Dis. Child.*, **92**(12), 1127–1131.

- [7] KALRA S., K. MEHRA, K. MURUGANANDHAM et al. (2020) Does diversion in poorly functioning obstructed kidneys in adults favors reconstructive surgeries over ablative procedures? A prospective study, *Cureus*, **12**(8), e10124.
- [8] ZHANG S., Q. ZHANG, C. JI et al. (2015) Improved split renal function after percutaneous nephrostomy in young adults with severe hydronephrosis due to ureteropelvic junction obstruction, *J. Urol.*, **193**, 191–195.
- [9] VAUGHAN E. D., J. Y. GILLENWATER (1971) Recovery following complete chronic unilateral ureteral occlusion: functional, radiographic, and pathologic alterations, *J. Urol.*, **106**, 27–35.
- [10] SINGH U. P., S. KAKOTI, S. K. SUREKA et al. (2022) Percutaneous nephrostomy in Ureteropelvic junction obstruction with poorly functioning kidney: Is it still pertinent in adults?, *Turk. J. Urol.*, **48**(3), 229–235.
- [11] JI A., J. YANG, Y. LI (2017) Added value of SPECT/CT for the evaluation of obstructive uropathy, *J. Nucl. Med.*, **58**(Supl. 1), 522.
- [12] MIYAZAKI C., H. HARADA, N. SHUKE et al. (2010) (99m)Tc-DTPA dynamic SPECT and CT volumetry for measuring split renal function in live kidney donors, *Ann. Nucl. Med.*, **24**(3), 189–195.
- [13] JUNG R. S., K. AGARWAL, A. SOOD et al. (2013) Hybrid SPECT/CT as a diagnostic modality in suspected urinoma with ambiguous planar Tc99m EC renal scintigraphy, *Indian J. Nucl. Med.*, **28**(4), 254–255.
- [14] MCALINDEN P., I. VLAHOS, M. MATSON, O. CHAN (2001) Imaging of renal trauma, *Imaging*, **13**, 44–58.
- [15] HARISANKAR C. N. B., B. R. MITTAL, A. BHATTACHARYA et al. (2008) Two urinomas after a renal allograft demonstrated by hybrid SPET-CT, *Hellenic J. Nucl. Med.*, **11**(3), 184.

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