LITERATURE REVIEWS

Medical Science of Ukraine
Медична наука України

ISSN: 2664-472X
e-ISSN: 2664-4738
Vol. 22, No. 2, 2026

UDC 616.61-089.843:616-073.756.8:616.61-089.819
DOI: https://doi.org/10.32345/2664-4738.2.2026.19

Journal homepage: https://nmuofficial.com/zhurnal-medychna-nauka-ukrayiny/
Received: 29.12.2025 Revised: 25.04.2026 Accepted: 28.05.2026 Published: 30.06.2026

**Sergii Zemskov***

PhD, Doctor of Medical Sciences, Professor
Bogomolets National Medical University
01601, 13 T. Shevchenko Blvd., Kyiv, Ukraine
https://orcid.org/0000-0002-5039-1324

**Larysa Natrus**

PhD, Doctor of Medical Sciences, Professor
Bogomolets National Medical University
01601, 13 T. Shevchenko Blvd., Kyiv, Ukraine
https://orcid.org/0000-0003-1763-0618

**Mykhailo Tkachenko**

PhD, Doctor of Medical Sciences, Professor
Bogomolets National Medical University
01601, 13 T. Shevchenko Blvd., Kyiv, Ukraine
https://orcid.org/0000-0003-4210-1566

**Iryna Krasyuk**

PhD in Medical Sciences, Associate Professor
Bogomolets National Medical University
01601, 13 T. Shevchenko Blvd., Kyiv, Ukraine
https://orcid.org/0000-0002-3483-5247

# Dynamic renal scintigraphy with 99mTc-DTPA in the differential diagnosis of acute tubular necrosis and acute renal allograft rejection in the early post-transplant period

## Abstract

**Relevance.** Worldwide, people recognise kidney transplantation as the standard treatment for end-stage kidney failure. However, impaired graft function frequently complicates the early postoperative period. The most common causes of early dysfunction are acute tubular necrosis and acute rejection. These conditions are difficult to distinguish from one another because they have similar clinical manifestations and routine monitoring methods are limited.

**Aim.** To describe the evidence relating to the diagnostic accuracy and capabilities of dynamic renal scintigraphy with 99mTc-DTPA in distinguishing acute tubular necrosis from renal allograft rejection.

**Materials and methods.** To identify relevant publications, searches were conducted in the international databases PubMed, Scopus, Web of Science and Google Scholar, with a focus on the period from January 2020 to January 2026. The analysis included studies that looked at how 99mTc-DTPA scintigraphy is used in adult kidney transplant patients. This was confirmed by either a biopsy or by checking the patient's progress over time. This review is limited by the fact that no formal risk-of-bias assessment was performed. A total of 22 sources were included in the final analysis. The comprehensiveness of the global evidence included in this review may have been affected by the fact that it was limited to English- and Ukrainian-language publications.

**Results.** Analysis of the literature indicates that the key criterion for scintigraphic differentiation is assessing the relationship between graft perfusion and function. Acute tubular necrosis is characterised by a dissociation phenomenon, with preserved perfusion despite reduced excretory function. In contrast, acute rejection is accompanied by a parallel deterioration in haemodynamics and function caused by increased vascular resistance.

**Suggested Citation**:
Zemskov S. Natrusk L, Tkachenko M, Krasyuk I. Dynamic renal scintigraphy with 99mTc-DTPA in the differential diagnosis of acute tubular necrosis and acute renal allograft rejection in the early post-transplant period. Med Sci Ukr. 2026;22(2):178–185. DOI: https://doi.org/10.32345/2664-4738.2.2026.19

*Corresponding author (*szemskov@yahoo.com*)

Using semi-automated quantitative parameters, particularly the Hilson and Kirchner indices, has been shown to strongly correlate with biopsy findings. According to the available literature, this method has a sensitivity of 98% for diagnosing acute tubular necrosis and 87% for detecting acute rejection. Even in cases of reduced graft function, 99mTc-DTPA is the optimal radiopharmaceutical for the routine assessment of perfusion indices thanks to its cost-effectiveness.

**Conclusions.** Dynamic renal scintigraphy with 99mTc-DTPA is an effective non-invasive diagnostic method. It enables haemodynamic abnormalities in the allograft to be detected at the preclinical stage. Quantitative perfusion indices provide an objective basis for the diagnostic process, allow reliable differentiation between ischaemic and immunological complications, and minimise the need for invasive procedures. This facilitates the timely selection of an appropriate treatment strategy.

**Keywords:** glomerular filtration rate; kidney transplantation; functional imaging; post-transplant complications; graft dysfunction; graft rejection; scintigraphic monitoring.

## INTRODUCTION

For patients with end-stage kidney failure, kidney transplantation is the most effective treatment available, offering significant improvements in both quality of life and life expectancy. However, despite continuous advances in surgical techniques and immunosuppressive therapy, the early postoperative period is often characterised by a high risk of graft dysfunction. The two most common causes of this condition are acute tubular necrosis and acute rejection. These conditions have almost identical clinical manifestations, but require fundamentally different therapeutic approaches. Therefore, accurately and promptly diagnosing these complications non-invasively is crucial for preserving allograft viability and avoiding unnecessary invasive procedures. This highlights the considerable scientific and practical importance of researching functional imaging techniques.

Leading researchers have actively investigated the problem of the early diagnosis of post-transplant complications in recent years. In particular, M. Strader & S. Kant [1] noted in their review that conventional biomarkers have limited sensitivity. Biomarkers such as serum creatinine represent "late" indicators of rejection. This creates an urgent need for the introduction of more sensitive imaging techniques. M. Ostermann *et al*. [2] emphasised that acute kidney injury, including tubular necrosis, is a major cause of early graft dysfunction, and that this must be immediately differentiated from immunological crises. The reliability of routine Doppler ultrasonography in distinguishing acute tubular necrosis from rejection during the early postoperative period was called into question by I. Ahmad *et al*. [3], who reported that the specificity of ultrasonographic markers is insufficient. In contrast, H. Ale Ali & P. Scherer [4] concluded that renal scintigraphy is a reliable tool for differentiating between these conditions, as it enables visualisation of the dissociation phenomenon (preserved perfusion in tubular necrosis), as opposed to the parallel deterioration in haemodynamics observed during rejection. Examining the effectiveness of radiopharmaceuticals, D. Theerakulpisut *et al*. [5] found that 99mTc-DTPA and 99mTc-MAG3 have similarly high predictive value. However, DTPA is the optimal agent for accurately assessing glomerular filtration. When evaluating alternative laboratory markers, M. Oellerich *et al*. [6] found that, while liquid biopsy based on the analysis of donor-derived cell-free DNA is specific for rejection, it is often limited in practice due to high costs and logistical constraints, making radionuclide diagnostics a more accessible option. As Y. Song *et al*. [7] showed, new non-invasive methods, including molecular imaging, are much better than standard clinical tests at detecting rejection before it becomes a clinical problem. Finally, Ukrainian researcher M. Nechaiev [8] demonstrated the considerable clinical value of renal scintigraphy in the timely detection of kidnemy allograft complications. He emphasised the importance of incorporating quantitative scintigraphic parameters into routine clinical practice to minimise the need for percutaneous biopsy.

This study aimed to summarise and systematise the current scientific evidence concerning the diagnostic capabilities of dynamic renal scintigraphy with 99mTc-DTPA as an effective tool for non-invasively diagnosing ischaemic and immunological injury to the kidney allograft in the early postoperative period.

## MATERIALS AND METHODS

The search was conducted in the PubMed, Scopus, Web of Science and Google Scholar databases using the following keywords: "kidney transplantation", "radionuclide imaging", "graft rejection" and "kidney tubular necrosis". It predominantly covered publications issued between January 2020 and January 2026. The inclusion criteria were: adult patients following kidney allotransplantation from deceased or living-related donors; dynamic renal scintigraphy with 99mTc-DTPA; analysis of the resulting data; histological verification by biopsy; and reported sensitivity, specificity and accuracy in detecting rejection of the transplanted kidney and acute tubular necrosis. The following were the exclusion criteria: individual case reports, experimental animal studies, articles without full-text availability and publications in languages other than English or Ukrainian. The study was designed and conducted as a descriptive narrative literature review. Given its descriptive design,

no formal assessment of the risk of systematic bias was performed, for example using AMSTAR tools. This is a recognised limitation of the present study. The aim was to provide a conceptual synthesis of the available approaches to differential diagnosis, not to produce a statistical synthesis.

An initial search of the PubMed, Scopus, Web of Science and Google Scholar databases identified 1,452 publications in total. After removing duplicates (n = 385), 1,067 articles remained for screening of titles and abstracts. At this stage, 982 studies were excluded because they were not relevant to the research topic, were concerned with paediatric practice or animal experiments, or did not examine the use of 99mTc-DTPA. The full texts of 85 publications were assessed in detail to determine their compliance with the inclusion criteria. However, 54 articles were excluded from the analysis, primarily due to the lack of histological verification of the findings, the exclusive use of tubule-targeting radiopharmaceuticals, or their format as individual clinical case reports. The final qualitative analysis included a total of 22 sources containing valid data on the use of dynamic renal scintigraphy for the differential diagnosis of postoperative complications.

## RESULTS AND DISCUSSION

For patients with end-stage kidney failure, kidney transplantation aims to prolong life and improve quality of life. This is achieved through open or laparoscopic surgery. The world's first successful kidney transplant was performed by Dr Joseph Murray in 1954. Since then, considerable time has elapsed, and substantial improvements have been made in the methods used to select and prepare recipients and donors, perform the surgical procedure, and manage patients postoperatively. Nevertheless, kidney transplantation is still associated with a number of complications that occur after surgery, and these are not always exclusively related to the surgical technique. The post-transplant period is conventionally divided into two periods. The first is the early period. This comprises the first three months. The second is the late period. The first months after a transplant are a time of particular vigilance, as this is when the risk of complications is increased. These include haemorrhage, thrombosis, infection, arterial stenosis, lymphocele, urinoma, ureteric stenosis, vesicoureteric reflux, acute or chronic rejection and acute tubular necrosis, among others [10-12].

Acute tubular necrosis is a multifactorial syndrome most commonly caused by ischaemic or nephrotoxic injury. It involves damage to renal tubular cells despite the major vessels remaining open, and is characterised by a rapid decline in the glomerular filtration rate. This results in the build-up of metabolic waste products in the body. The most common cause of graft failure is acute tubular necrosis, which occurs in 50% of cases following ciclosporin administration, particularly during the early post-transplant period [2, 13]. The immunological reaction known as acute rejection usually happens between a few days and a few weeks after a transplant. The development of circulating donor-specific alloantibodies is a possible complication, and the condition may also be accompanied by immunological features of antibody-mediated renal injury, such as glomerulitis or peritubular capillaritis. Another possible cause is a T-cell-mediated response, which is marked by the presence of lymphocytes in the tubules and interstitium. In rare cases, this response can also lead to inflammation of the arterial intima. The incidence of acute rejection during the first year is approximately 7.9%. This complication occurs less frequently following living-donor transplantation than deceased-donor transplantation, possibly due to shorter cold ischaemia time and better donor–recipient matching [11]. Both complications may present with non-specific shared symptoms. These include oliguria or anuria, peripheral oedema, elevated blood pressure and increased serum creatinine levels. Acute rejection may occasionally present with a low-grade fever, pain in the graft area, general weakness and myalgia, which are not classically observed in acute tubular necrosis. However, all these symptoms are non-specific. This means they always require differentiation from other pathological conditions. Some of these may not be directly related to kidney transplantation.

Dynamic renal scintigraphy is a nuclear medicine technique which allows renal function to be assessed quantitatively and qualitatively by administering specific radiopharmaceuticals. This involves monitoring their distribution dynamically from the moment of intravenous administration until scanning is complete (Fig. 1). A wide range of instrumental and laboratory investigations is used in clinical practice. Each has its own advantages and disadvantages. These are important in the differential diagnosis of these complications. Measurement of serum creatinine and calculation of the estimated glomerular filtration rate are standard components of routine monitoring. However, creatinine is a non-specific marker and does not respond immediately to structural damage to the renal parenchyma, which can prevent the problem from being detected straight away [1, 2, 14]. As well as creatinine, modern laboratory diagnostics offer several other biomarkers, including cystatin C, neutrophil gelatinase-associated lipocalin and cell-free DNA derived from the donor. Cystatin C is a more sensitive marker of declining glomerular filtration than creatinine, enabling earlier diagnosis of graft dysfunction. Neutrophil gelatinase-associated lipocalin, in turn, has been established as an early predictor of acute kidney injury. However, a major limitation of both cystatin C and neutrophil gelatinase-associated lipocalin is their lack of specificity, which prevents them from being used for differential diagnosis. In contrast, donor-derived cell-free DNA, also known as a "liquid biopsy", is a highly

specific indicator of active rejection, particularly antibody-mediated rejection. Meta-analyses have shown that an increase in the donor-derived cell-free DNA fraction above 1% clearly correlates with the histological features of rejection. In contrast, this parameter usually remains low in uncomplicated acute tubular necrosis [6]. It is important to note that testing for neutrophil gelatinase-associated lipocalin and donor-derived cell-free DNA is difficult to access in Ukraine due to complicated logistics and high costs.

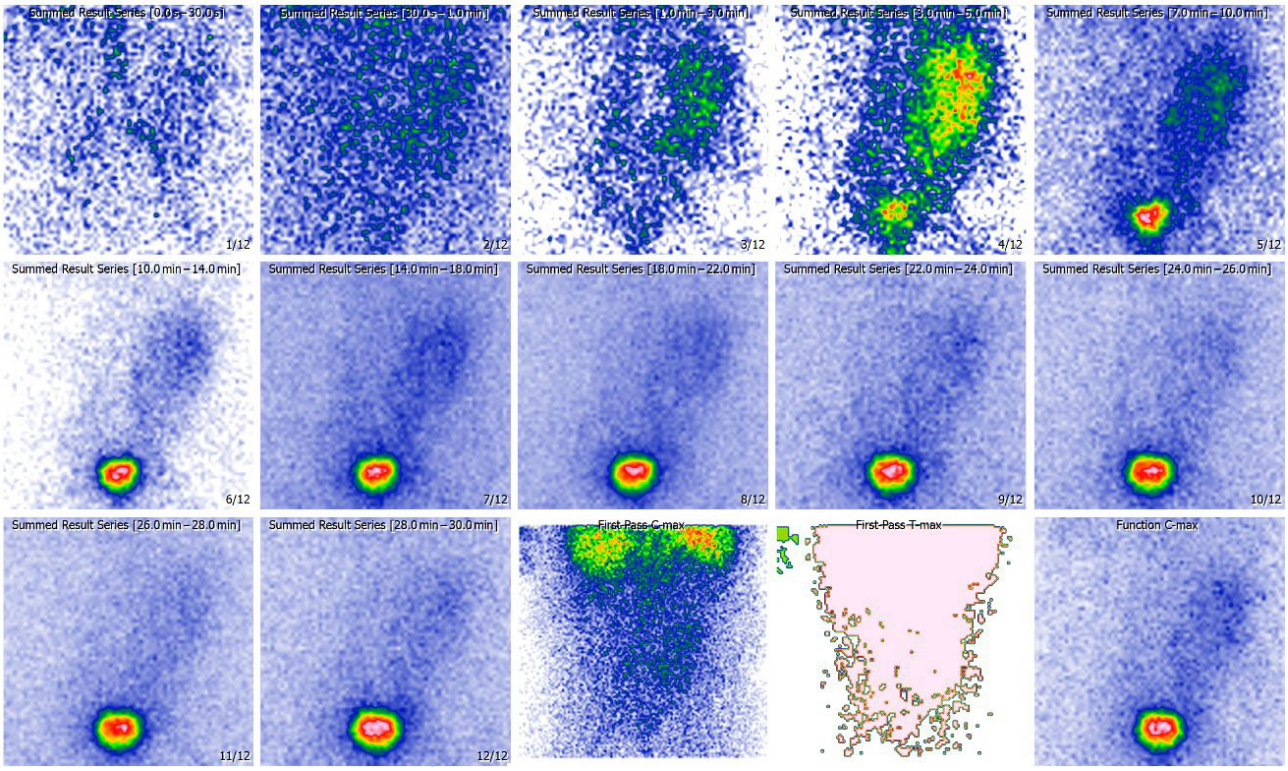


**Figure 1.** Dynamic renal scintigraphy of a transplanted kidney

**Note:** Stages 1-12 (shown in the upper and middle rows) represent dynamic images of summed activity from 0 to 30 minutes. Stage 1, corresponding to 0-30 seconds, represents the angiographic phase of graft perfusion. Stages 2-4 (30 seconds to 5 minutes) demonstrate the parenchymal phase, during which peak glomerular filtration of 99mTc-DTPA is reached. Stages 5-12 (7-30 minutes) represent the excretory phase, showing gradual parenchymal clearance and accumulation of the radiopharmaceutical in the urinary bladder. This confirms the absence of urodynamic obstruction. Stages 13-15, shown in the lower right-hand row, represent parametric maps. Stages 13 and 14 (First-Pass C-max and First-Pass T-max, respectively) demonstrate the regions of maximum perfusion amplitude and velocity during the first passage of the bolus. Stage 15, Function C-max, shows the spatial distribution of the most functionally active allograft parenchyma

**Source:** authors' photo

Ultrasonography, including Doppler ultrasonography, is the preferred imaging method due to its accessibility, lack of radiation exposure and absence of contraindications. It is effective in detecting surgical complications such as urinomas and lymphoceles, as well as in assessing blood flow in major vessels. However, the resistive index, which is used as a marker of parenchymal oedema, depends on the operator and is non-specific. It may be elevated in cases of rejection, acute tubular necrosis, obstruction, and other conditions [3, 12]. High-resolution images are provided by computed tomography, which also enables detailed visualisation of the graft anatomy and surrounding tissues. However, its use is limited by the fact that contrast agents, which are often necessary, can be nephrotoxic and the procedure involves a relatively high radiation dose [16-18]. Magnetic resonance imaging is a safer imaging method. This is particularly true of functional magnetic resonance imaging. The latter is increasingly discussed in the literature. Functional magnetic resonance imaging provides detailed anatomical images as well as information on changes in diffusion, oxygenation, perfusion, metabolism and graft microstructure. However, its use is limited. This is because of the cost of the examination. It is also limited by the shortage of appropriately trained specialists in Ukraine [19]. Ultrasound-guided biopsy remains the gold standard for differential diagnosis, enabling the type of rejection and severity of tubular necrosis to be verified. However, it is an invasive procedure associated with the risk of haemorrhage, arteriovenous fistula formation, and graft loss, which limits its use in serial monitoring [12, 20].

99mTc-DTPA is one of the most commonly used radiopharmaceuticals. It consists of a technetium isotope and diethylenetriaminepentaacetic acid. Glomerular filtration is how it is eliminated, and this allows the glomerular filtration rate to be calculated. It also allows the differential functional and excretory capacity of each kidney to be assessed, and it can be used to identify impaired urinary drainage [5, 21]. Importantly, 99mTc-DTPA is not nephrotoxic. Therefore, it can be used regardless of the functional status of the graft, avoiding the complications associated with certain other diagnostic procedures. According to the latest recommendations of the European Association of Nuclear Medicine, its main uses include the diagnosis of acute and chronic kidney failure, unilateral or bilateral kidney disease (including neoplasms), obstructive uropathy, renovascular hypertension, post-transplant conditions, pyelonephritis, and parenchymal scarring [4, 12].

One of the major advantages of dynamic renal scintigraphy is that it does not require any special preparation from the patient. Patients do not need to follow a special diet or fast, and they can maintain an adequate level of hydration. In kidney transplant recipients, the main focus of diagnosis is differentiating between acute tubular necrosis and graft rejection [5]. This purpose is served by the Hilson perfusion index and the Kirchner function index, or their modifications [8, 22]. The Hilson perfusion index is the ratio of the area under the bolus transit curve for the iliac artery or aorta. This is divided by the area under the renal curve. This is over the interval preceding the peak of the arterial curve. It is calculated using the following formula: HI = Area under the arterial curve / Area under the renal curve ×100. A value below 150 is considered normal, or below 1.5 when modified indices are used [4, 22]. The Kirchner function index is the ratio of the rate of increase in renal activity. This is represented by the slope of the renal curve. It is compared to the rate of increase in activity in the aorta or iliac artery. This is during the first passage of the bolus. It is calculated using the following formula: KI = slope of the renal curve / slope of the aortic curve. The function index is considered normal when its value is above 2.5 [8, 22]. The two indices were shown to be useful in the diagnosis of acute tubular necrosis and allograft rejection. Scintigraphic findings were concordant with biopsy findings in 86% of cases [4, 5, 22]. Acute tubular necrosis is characterised by a reduction in the function index, while the perfusion index remains normal or only slightly elevated. In contrast, acute rejection is characterised by a marked increase in the Hilson index, exceeding 250 when the conventional index is used and 2.5 when the modified index is used, while the Kirchner index decreases sharply to below 1.5 [4, 8, 22].

Analysis of the literature confirms that the differential diagnosis of early complications following kidney transplantation is a significant clinical challenge that requires highly sensitive methods [10-11]. This study's main finding is that dynamic renal scintigraphy with 99mTc-DTPA provides an early, objective assessment of graft haemodynamics at the preclinical stage [14]. The conclusions regarding the appropriateness of routinely using dynamic renal scintigraphy are similar to those of M. Strader & S. Kant [1], who emphasised that conventional markers such as serum creatinine are delayed indicators that respond only after irreversible structural changes have occurred. In contrast, the present study's findings indicate that dynamic renal scintigraphy can detect functional abnormalities immediately. M. Oellerich *et al*. [6] concentrated on the high specificity of liquid biopsy based on donor-derived cell-free DNA for detecting acute rejection when evaluating alternative diagnostic markers. While the authors of this study recognise the high diagnostic value of this laboratory test, their analysis suggests that in settings with limited resources and complex logistics, using readily available 99mTc-DTPA is a more rational and rapid option for routine monitoring.

The findings regarding the benefits of radionuclide imaging are fully consistent with those of I. Ahmad *et al*. [3], who showed that, despite its accessibility, routine Doppler ultrasonography cannot reliably distinguish between acute tubular necrosis and rejection due to the non-specific nature of the resistive index. In contrast, this review shows that dynamic renal scintigraphy can overcome this limitation by visualising the dissociation phenomenon. This is a key pathognomonic feature, where preserved perfusion combined with impaired function clearly indicates tubular necrosis. Furthermore, the authors of this study emphasise that the administration of nephrotoxic contrast agents during the early postoperative period is unacceptable, unlike approaches that promote the use of computed tomography [16, 18]. This makes the use of the functionally safe radiopharmaceutical 99mTc-DTPA a uniquely suitable option [12, 21].

The present findings concerning the choice of radiopharmaceutical are also relevant. They should be compared with the study by D. Theerakulpisut *et al*. [5]. This study found equally high predictive values for both 99mTc-DTPA and the tubule-targeting agent 99mTc-MAG3. However, the authors of the present study emphasise something different. They say that the main aim in the differential diagnosis of acute rejection is the assessment of the haemodynamic phase. By this they mean the first passage of the bolus. This phase depends on the quality of radiopharmaceutical administration rather than its excretory mechanism. The authors of the present study demonstrate that the more cost-effective 99mTc-DTPA can be successfully used to calculate the required Hilson and Kirchner perfusion indices. It remains the radiopharmaceutical of choice for routine screening (Table 1).

**Table 1.** Comparative characteristics of DTPA and MAG3

| Parameter | DTPA | MAG3 |
|---|---|---|
| Radiopharmaceutical class | Glomerular filtration agent | Tubular excretion agent |
| Mechanism | Freely filtered by the glomeruli without tubular secretion | Secreted by proximal tubular cells through active transport |
| Parameters assessed | Glomerular filtration rate, excretion and differential renal function | Renal perfusion, tubular function, excretion and differential renal function |
| Clinical applications | Obstructive uropathy, postoperative assessment and renal graft evaluation | Obstructive uropathy, for which it is preferred, renal graft evaluation and renal artery stenosis |
| Advantages | Pure marker of glomerular filtration; low radiation exposure | More effective in kidney failure; effective in obstruction |
| Limitations | Less effective in severe obstruction because of weak secretion | Slightly higher radiation exposure; more expensive |
| Routine dose | 1-2 mCi (37-74 MBq) | 2-4 mCi (74-148 MBq) |
| Plasma half-life | Approximately 100 minutes | Approximately 15-20 minutes |
| Principal conclusion | DTPA: filtration and drainage | MAG3: secretion and obstruction |

**Source:** compiled by the authors

Finally, the present findings regarding the necessity of mathematically objectifying scintigraphic images are directly supported by the work of H. Ale Ali & P. Scherer [4], as well as the studies of M. Nechaev [8, 22]. In agreement with these authors, the authors of the present study concluded that visual image assessment alone is insufficient. Only by integrating semi-automated indices can the diagnostic sensitivity reported in the international literature be achieved. The Hilson index above 2.5 indicates rejection, whereas an index below 2.0 combined with a reduced Kirchner index indicates tubular necrosis. This approach provides sensitivities of up to 98% and 87% for ischaemic and immunological complications, respectively [4, 22]. Overall, the comparative analysis confirms that innovative, non-invasive, molecular imaging approaches can substantially reduce the need for traumatic, percutaneous biopsy. According to J.M. Halimi *et al*. [20], this procedure remains associated with a considerable risk of complications.

In summary, the choice of a particular radiopharmaceutical should be based on the principal clinical objectives. It should also take the patient's overall functional status into account. While 99mTc-MAG3 clearly has advantages for visualising the renal parenchyma in cases of severe obstruction or critically impaired excretory function, 99mTc-DTPA remains the optimal first-line tool for routine postoperative screening. Key perfusion parameters, particularly the Hilson and Kirchner indices, can be objectively calculated using the pharmacokinetic properties of 99mTc-DTPA as a pure marker of glomerular filtration. These measurements are essential for rapidly and reliably differentiating immunological complications, such as rejection, from ischaemic complications, such as tubular necrosis. A reliable, non-invasive diagnostic algorithm is provided by a comprehensive analysis of haemodynamic scintigraphic parameters, particularly when integrated with modern laboratory biomarkers. This multimodal approach can significantly improve the clinical management of recipients during the early post-transplant period and reduce the need for high-risk percutaneous biopsy.

## CONCLUSIONS

1. Dynamic renal scintigraphy using 99mTc-DTPA is an effective, non-invasive diagnostic method that can detect haemodynamic abnormalities in the allograft at the preclinical stage.

2. The key criterion for scintigraphic differentiation is assessing the relationship between graft perfusion and function. Acute tubular necrosis is characterised by a dissociation phenomenon, with preserved perfusion despite reduced excretory function. In contrast, acute rejection is accompanied by a parallel deterioration in both parameters.

3. Using semi-automated quantitative parameters, particularly the Hilson and Kirchner indices, provides an objective basis for the diagnostic process and demonstrates a strong correlation with biopsy findings.

4. The high sensitivity and specificity of dynamic renal scintigraphy confirm its status as a reliable differential diagnostic tool for the timely identification of ischaemic and immunological graft injury.

5. Using cost-effective, non-nephrotoxic 99mTc-DTPA minimises the need for invasive procedures and facilitates timely selection of an appropriate treatment strategy during the early postoperative period.

**Limitations.** Firstly, due to the descriptive nature of this narrative review, no formal assessment of the risk of systematic bias was conducted. Second, the literature search was limited to English- and Ukrainian-language publications only, which may have affected the comprehensiveness of the global evidence included.

## ACKNOWLEDGEMENTS

None.

## FUNDING

During the preparation of this manuscript, no specific funding was received from any public or private organisation.

## CONFLICT OF INTEREST

There is no conflict of interest. The authors of the article did not take part in the peer-review process or in editorial decisions regarding their own manuscript.

## REFERENCES

[1] Strader M, Kant S. Novel biomarkers for rejection in kidney transplantation: A comprehensive review. J Clin Med. 2025;14(15):5489. DOI: 10.3390/jcm14155489
[2] Ostermann M, Lumlertgul N, Jeong R, See E, Joannidis M, James M. Acute kidney injury. Lancet. 2025;405(10474):241–56. DOI: 10.1016/S0140-6736(24)02385-7
[3] Ahmad I, Yadav P, Alshammari D, Khondker A, Santos JD, Rickard M, et al. Routine doppler ultrasonography does not differentiate acute tubular necrosis and rejection in early pediatric kidney transplantation. Pediatr Transplant. 2025;7:e70172. DOI: 10.1111/petr.70172
[4] Ale Ali H, Scherer P. Renal scintigraphy following kidney transplantation – ATN, rejection, and more. J Nucl Med. 2022;63(2):2668.
[5] Theerakulpisut D, Thinkhamrop B, Anutrakulchai S. Comparison between Tc-99 m DTPA and Tc-99 m MAG3 renal scintigraphy for prediction of early adverse outcome after kidney transplantation. Nucl Med Mol Imaging. 2021;55(6):302–10. DOI: 10.1007/s13139-021-00716-4
[6] Oellerich M, Budde K, Osmanodja B, Bornemann-Kolatzki K, Beck J, Schütz E, et al. Donor-derived cell-free DNA as a diagnostic tool in transplantation. Front Genet. 2022;13:1031894. DOI: 10.3389/fgene.2022.1031894
[7] Song Y, Wang Y, Wang W, Xie Y, Zhang J, Liu J, et al. Advancements in noninvasive techniques for transplant rejection: From biomarker detection to molecular imaging. J Transl Med. 2025;23:147. DOI: 10.1186/s12967-024-05964-4
[8] Nechaiev M. Diagnostic value of renal scintigraphy in detecting early kidney allograft complications. Ukr J Nephrol. 2026;1(89):25–34. DOI: 10.31450/ukrjnd.1(89).2026.04
[9] Abramyan S, Hanlon M. Kidney transplantation. In: StatPearls. Treasure Island: StatPearls Publishing; 2025.
[10] Yamanaka K, Kakuta Y, Nakazawa S, Kobayashi K, Nonomura N, Kageyama S. Surgical and infectious complications following kidney transplantation: A contemporary review. J Clin Med. 2025;14(10):3307. DOI: 10.3390/jcm14103307
[11] Naik RH, Hassanein M, Shawar SH. Acute renal transplantation rejection. In: StatPearls. Treasure Island: StatPearls Publishing; 2025.
[12] Breda A, Budde K, Figueiredo A, Lledó García E, Olsburgh J, Regele H, et al. EAU Guidelines on Renal Transplantation. Arnhem: EAU Guidelines Office; 2026. 58 P.
[13] Elmi A, Arabsorkhi Mishabi M, Teymoori E, Nikbakht D, Sarraf N, Jabinian E, et al. A systematic review of the relationship between acute tubular necrosis and kidney transplantation. J Renal Inj Prev. 2021;10(3):e18. DOI: 10.34172/jrip.2021.18
[14] Nechaiev M. Multimodal assessment of early kidney allograft complications: Role of renal scintigraphy and laboratory biomarkers. Ukr J Nephrol Dial. 2026;2(90):42–50. DOI: 10.31450/ukrjnd.2(90).2026.05
[15] Marakala V. Neutrophil gelatinase-associated lipocalin (NGAL) in kidney injury – a systematic review. Clin Chim Acta. 2022;536:135–41. DOI: 10.1016/j.cca.2022.08.029
[16] Modi K, Padala SA, Gupta M. Contrast-induced nephropathy. In: StatPearls. Treasure Island: StatPearls Publishing; 2025.
[17] Jones J, Bickle I. Contrast-induced acute kidney injury. Reference article, Radiopaedia.org. 2010. DOI: 10.53347/rID-10252
[18] Inoue Y. Radiation dose management in computed tomography: Introduction to the practice at a single facility. Tomography. 2023;9(3):955–66. DOI: 10.3390/tomography9030078
[19] Ma J, Jiang B, Wan J, Xu R, Que C, Zhu M. Progress of functional magnetic resonance imaging in the assessment of transplanted kidney function. Ren Fail. 2025;47(1):2560602. DOI: 10.1080/0886022X.2025.2560602
[20] Halimi JM, Gatault P, Longuet H, Barbet C, Bisson A, Sautenet B, et al. Major bleeding and risk of death after percutaneous native kidney biopsies: A French nationwide cohort study. Clin J Am Soc Nephrol. 2020;15(11):1587–94. DOI: 10.2215/cjn.14721219
[21] National Center for Biotechnology Information. PubChem compound summary for CID 126480242, Technetium-99mTc-DTPA [Internet]. 2017 April 16 [cited 2026 January 4]. Available from: https://pubchem.ncbi.nlm.nih.gov/compound/Technetium-99mTc-DTPA
[22] Nechaiev MP. Renal scintigraphy of the transplanted kidney: Innovative approaches to monitoring and prognostic value. Ukr J Nephrol Dial. 2025;4(88):63–71. DOI: 10.31450/ukrjnd.4(88).2025.08

**Сергій Земсков**

Доктор філософії, доктор медичних наук, професор
Національний медичний університет ім. О. О. Богомольця
01601, бульв. Т. Шевченка, 13, м. Київ, Україна
https://orcid.org/0000-0002-5039-1324

**Лариса Натрус**

Доктор філософії, доктор медичних наук, професор
Національний медичний університет ім. О. О. Богомольця
01601, бульв. Т. Шевченка, 13, м. Київ, Україна
https://orcid.org/0000-0003-1763-0618

**Михайло Ткаченко**

Доктор філософії, доктор медичних наук, професор
Національний медичний університет ім. О. О. Богомольця
01601, бульв. Т. Шевченка, 13, м. Київ, Україна
https://orcid.org/0000-0003-4210-1566

**Ірина Красюк**

Кандидат медичних наук, доцент
Національний медичний університет ім. О. О. Богомольця
01601, бульв. Т. Шевченка, 13, м. Київ, Україна
https://orcid.org/0000-0002-3483-5247

# Динамічна реносцинтиграфія з 99mTc-DTPA у диференційній діагностиці гострого тубулярного некрозу та гострого відторгнення ниркового трансплантата в ранньому посттрансплантаційному періоді

**Анотація**

**Актуальність.** Трансплантація нирки є визнаним у світі стандартом лікування термінальної стадії ниркової недостатності, проте ранній післяопераційний період часто ускладнюється порушенням функції трансплантата. Найпоширенішими причинами ранньої дисфункції є гострий тубулярний некроз та гостре відторгнення, диференційна діагностика яких залишається складною через схожість клінічної симптоматики та обмеження рутинних методів моніторингу.

**Мета.** Описовий огляд даних щодо діагностичної точності та можливостей динамічної реносцинтиграфії з 99mTc-DTPA у розрізненні гострого тубулярного некрозу та відторгнення трансплантата.

**Матеріали та методи.** Пошук релевантних публікацій проводився у міжнародних базах даних PubMed, Scopus, Web of Science та Google Scholar, охоплюючи період переважно з січня 2020 року по січень 2026 року. До аналізу було включено дослідження, що розглядали застосування сцинтиграфії з 99mTc-DTPA у дорослих після алотрансплантації нирки з верифікацією діагнозу шляхом біопсії або клінічного спостереження. Оцінка ризику систематичних похибок формально не проводилась, що розглядається як обмеження даного огляду. У фінальний аналіз було включено 22 джерела. Слід враховувати, що даний огляд обмежувався аналізом англо- та україномовних публікацій, що могло вплинути на повноту охоплення світових даних.

**Результати.** Аналіз джерел свідчить, що ключовим критерієм сцинтиграфічної диференціації є оцінка співвідношення перфузії та функції трансплантата. Гострий тубулярний некроз характеризується феноменом дисоціації (збережена перфузія на тлі зниженої екскреторної функції), тоді як гостре відторгнення супроводжується симетричним погіршенням гемодинаміки та функції внаслідок підвищення судинного опору. Встановлено, що використання напівавтоматичних кількісних параметрів, зокрема індексів Хілсона та Кіршнера, забезпечує високу кореляцію з результатами біопсії. Згідно з даними літератури, чутливість методики сягає 98 % для діагностики гострого тубулярного некрозу та 87 % для виявлення гострого відторгнення. Економічно доступний 99mTc-DTPA залишається оптимальним агентом для рутинної оцінки перфузійних індексів навіть при зниженій функції трансплантата.

**Висновки.** Динамічна реносцинтиграфія з 99mTc-DTPA є ефективним неінвазивним методом діагностики, що дозволяє виявляти порушення гемодинаміки алотрансплантата на доклінічному етапі. Використання кількісних індексів перфузії дозволяє об'єктивізувати діагностичний процес, надійно розрізняти ішемічні та імунологічні ускладнення та мінімізувати необхідність проведення інвазивних втручань, сприяючи своєчасному вибору адекватної тактики лікування.

**Ключові слова:** швидкість клубочкової фільтрації; трансплантація нирки; функціональна візуалізація; посттрансплантаційні ускладнення; дисфункція трансплантата; відторгнення трансплантата; сцинтиграфічний моніторинг.