Ukrainian Journal of Nephrology and Dialysis
Scientific and Practical, Medical Journal

Founder:
- National Kidney Foundation of Ukraine

ISSN 2304-0238;
eISSN 2616-7352

Journal homepage: https://ukrjnd.com.ua

Research article

doi: 10.31450/ukrjnd.1(89).2026.04

Mykyta Nechaiev

Diagnostic value of renal scintigraphy in detecting early kidney allograft complications

[1]State Non-Commercial Enterprise «National Children's Specialized Hospital «Okhmatdyt» Ministry of Health of Ukraine», Kyiv, Ukraine
[2]Bogomolets National Medical University, Kyiv, Ukraine

Citation: Nechaiev MP. Diagnostic value of renal scintigraphy in detecting early kidney allograft complications. Ukr J Nephrol Dialys. 2026;1(89):25-34. doi: 10.31450/ukrjnd.1(89).2026.04.

Abstract. *Early identification of kidney allograft complications is essential for preserving graft function. Serum creatinine is routinely used for post-transplant complications monitoring but has a lack of specificity in the early period. Imaging methods such as ultrasound (US) and renal scintigraphy (RS) provide complementary structural and functional information. The study aimed to assess temporal changes in scintigraphy perfusion index (PI), function index (FI), and glomerular filtration rate (GFR) in early kidney allograft complications and to compare these findings with ultrasonographic parameters.*

Methods. This single-center observational study included 65 kidney transplant recipients examined within the first 7 days post-transplantation. Thirty-two patients with stable graft function served as controls, while 33 patients developed early allograft complications. All patients underwent dynamic ^{99m}Tc-DTPA renal scintigraphy with calculation of the PI, FI and GFR on postoperative days 1, 3, and 7, as well as Doppler ultrasonography. Quantitative data were compared using nonparametric tests; $p<0.05$ was considered statistically significant.

Results. Early complications included acute rejection (31%), ureteral stenosis (22%), urinary fistula (16%), infectious complications (12%), renal artery thrombosis (11%) and renal vein thrombosis (8%). In acute rejection, PI decreased from 0.76 on day 3 to 0.55 on day 7 ($p<0.0001$), accompanied by reductions in FI (from 0.78 to 0.50, $p<0.0001$) and GFR from 39.5 to 25.3 mL/min/1.73 m^2 ($p<0.0001$). Vascular thromboses showed the most pronounced decreases in all scintigraphy indices ($p<0.0001$). Ureteral stenosis demonstrated a progressive decline in PI, FI, and GFR between days 3 and 7 ($p<0.0001$), whereas urinary fistula and infectious complications showed no significant scintigraphic changes ($p>0.05$). Doppler-derived resistive index elevation was predominantly detected on day 7, later than scintigraphic abnormalities.

Conclusions. These results support the role of RS as an adjunct imaging modality for early post-transplant assessment and show early allograft complications much more effectively than ultrasound. Further prospective studies are needed to validate quantitative thresholds and diagnostic accuracy.

Keywords: *kidney transplantation, renal scintigraphy, acute rejection, ureteral stenosis, vascular thrombosis, perfusion index, function index, early post-transplant complications.*

Article history:
Received November 17, 2025
Received in revised form January 15, 2026
Accepted January 16, 2026

Conflict of interest. The author declares no conflict of interest.

Correspondence should be addressed to Mykyta Nechaiev: m.nechaiev@ohmatdyt.com.ua

УДК: 616.61-089.843-06:616.61-073.756.6

Микита Нечаєв

Діагностична цінність ренальної сцинтиграфії у виявленні ранніх ускладнень ниркового трансплантата

Державне некомерційне підприємство «Національна дитяча спеціалізована лікарня «ОХМАТДИТ» МОЗ України», Київ, Україна

НМУ імені О.О. Богомольця, Київ, Україна

Резюме. *Раннє виявлення ускладнень трансплантата нирки є ключовим для збереження його функції. Сироватковий креатинін широко використовується для моніторингу післятрансплантаційних ускладнень, однак у ранньому періоді він характеризується низькою специфічністю. Методи візуалізації, зокрема ультразвукове дослідження (УЗД) та сцинтиграфія нирок (СН), надають взаємодоповнювальну інформацію щодо структурних і функціональних змін трансплантата. Метою дослідження було оцінити часову динаміку сцинтиграфічного індексу перфузії (PI), індексу функції (FI) та швидкості клубочкової фільтрації (ШКФ) при ранніх ускладненнях трансплантата нирки та порівняти ці показники з ультразвуковими параметрами.*

Методи. Проведено одноцентрове обсерваційне дослідження, яке включало 65 реципієнтів трансплантованої нирки, обстежених упродовж перших 7 діб після трансплантації. 32 пацієнти зі стабільною функцією трансплантата становили контрольну групу, тоді як у 33 пацієнтів розвинулися ранні ускладнення трансплантата. Усім пацієнтам виконували динамічну сцинтиграфію нирок з ^{99m}Tc-DTPA з розрахунком PI, FI та ШКФ на 1-шу, 3-тю та 7-му післяопераційні доби, а також доплерівське ультразвукове дослідження. Кількісні дані порівнювали з використанням непараметричних статистичних тестів; рівень статистичної значущості визначали як $p<0,05$.

Результати. До ранніх ускладнень належали гостре відторгнення (31%), стеноз сечоводу (22%), сечова нориця (16%), інфекційні ускладнення (12%), тромбоз ниркової артерії (11%) та тромбоз ниркової вени (8%). При гострому відторгненні PI знижувався з 0,76 на 3-тю добу до 0,55 на 7-му добу ($p<0.0001$), що супроводжувалося зменшенням FI (з 0.78 до 0.50, $p<0.0001$) та ШКФ з 39.5 до 25.3 мл/хв/1,73 м^2 ($p<0.0001$). Судинні тромбози характеризувалися найбільш вираженим зниженням усіх сцинтиграфічних індексів ($p<0.0001$). При стенозі сечоводу відзначали поступове зниження PI, FI та ШКФ між 3-тею і 7-мою добами ($p<0.0001$), тоді як при сечовій нориці та інфекційних ускладненнях значущих змін сцинтиграфічних показників не виявлено ($p>0.05$). Підвищення резистивного індексу за даними доплерографії переважно реєстрували на 7-му добу, пізніше, ніж сцинтиграфічні порушення.

Висновки. Отримані результати підтверджують доцільність використання СН як специфічного методу візуалізації для ранньої післятрансплантаційної оцінки та свідчать про її вищу ефективність у ранньому виявленні ускладнень порівняно з ультразвуковим дослідженням. Подальші проспективні дослідження необхідні для валідації кількісних порогових значень і діагностичної точності методу.

Ключові слова: *трансплантація нирки, сцинтиграфія нирок, гостре відторгнення, стеноз сечоводу, судинний тромбоз, індекс перфузії, індекс функції, ранні післятрансплантаційні ускладнення.*

Introduction. A kidney transplant remains the treatment of choice for patients with chronic kidney disease (CKD) that has progressed to end-stage renal disease (ESRD). At this stage, the kidneys lose their functions, i.e. ability to eliminate metabolic waste, toxins, and excess fluids from the blood, making transplantation the most effective method to restore renal function and improve long-term survival [1]. Despite continuous advances in surgical techniques and immunosuppressive therapy, early post-transplant complications remain a major cause of graft dysfunction and loss. Among these, acute rejection (AR) occurs in approximately 10–15% of recipients and represents a critical event that can significantly affect both short- and long-term graft survival [2].

Traditionally, serum creatinine (sCr) is the most commonly used marker for monitoring graft function worldwide. However, sCr is a late and nonspecific indicator. It often increases only after substantial nephron loss. In the early post-transplant period, sCr elevation may result from various causes, such as rejection, ischemia-reperfusion injury, obstruction, or vascular thrombosis. Therefore, serum creatinine is an unreliable marker for differential diagnosis [3, 4]. A renal biopsy is typically performed to confirm or exclude rejection. However, this method is very harmful and complicated [5].

Mykyta Nechaiev
m.nechaiev@ohmatdyt.com.ua

Ultrasound (US) is routinely used as the first-line imaging technique in both the early and late post-transplant periods. US is non-invasive, widely available, and free from ionizing radiation. Conventional B-mode ultrasound enables assessment of graft morphology, parenchymal echogenicity, and the detection of structural abnormalities. Doppler ultrasound further provides real-time information about intrarenal and graft vascular flow [6]. However, ultrasound findings are sometimes non-specific and may depend on operator experience, which limits its diagnostic precision in differentiating the cause of the transplant rejection.

Renal scintigraphy (RS) serves as a complementary nuclear medicine technique that provides quantitative and functional assessment of renal perfusion, parenchymal uptake, and urinary excretion. It enables dynamic evaluation of graft physiology in a single, non-invasive study.

In international clinical practice, dynamic RS is widely used for functional assessment of kidney allografts, providing quantitative parameters such as the perfusion index (PI), function index (FI), and glomerular filtration rate (GFR). PI reflects early graft hemodynamics and vascular integrity, FI represents parenchymal tracer uptake and functional capacity, and GFR offers an early estimate of graft filtration. The most commonly used radiopharmaceuticals include ^{99m}Tc-diethylenetriaminepentaacetic acid (^{99m}Tc-DTPA), ^{99m}Tc-mercaptoacetyltriglycine (^{99m}Tc-MAG3), and ^{99m}Tc-ethylenedicysteine (^{99m}Tc-EC) [7,8]. Alternative approaches for evaluating graft dysfunction include Doppler ultrasonography, contrast-enhanced ultrasound, magnetic resonance imaging and biopsies. However, ultrasound parameters such as the resistive index often demonstrate delayed or non-specific changes; advanced imaging modalities may be limited by availability or contraindications [7]. At the same time, biopsy remains invasive and unsuitable for frequent monitoring [2, 4]. This study addresses this gap by systematically evaluating scintigraphy indexes in the early post-transplant period and comparing their diagnostic performance with Doppler ultrasound across a spectrum of acute kidney allograft complications.

Materials and methods. *Study design*. This was an exploratory, single-center observational study including all consecutive eligible kidney transplant recipients. Therefore, no sample size calculation was performed. The final cohort comprised 65 patients. Post hoc analysis indicates that this sample size was sufficient to detect statistically significant differences in key scintigraphy parameters between groups. The study protocol was approved by the local institutional ethics committee (Protocol №14 from 07.04.2025) and conducted in accordance with the Declaration of Helsinki. All patients signed written informed consent.

Patient selection. A total of 65 renal scintigraphy studies from 65 patients were done. Each patient underwent a ^{99m}Tc-DTPA renal scintigraphy between the 1st day and 7th day after kidney transplantation. At the study institution, routine renal scintigraphy was performed within the first 24 hours post-transplant as a baseline assessment. Follow-up studies were repeated whenever graft dysfunction or complications were suspected. Ultrasound examinations were also performed when clinically indicated. Other diagnostic assessments, such as serum creatinine measurement and complete blood count (CBC), were conducted for all patients.

Patients were consecutively included if they underwent both ^{99m}Tc-DTPA renal scintigraphy and renal ultrasound at comparable time points after kidney transplantation. Patients were excluded in cases of primary graft non-function, delayed graft function requiring dialysis at the time of imaging, hemodynamic instability (vasopressor support), major perioperative complications requiring additional surgery, severe systemic infection or sepsis, or incomplete imaging or laboratory data. These criteria were applied to reduce confounding effects on graft perfusion and function. Renal scintigraphy and ultrasound were performed on the same day or within a 24-hour interval in all included cases, minimizing temporal bias in the comparison of imaging findings.

Renal scintigraphy studies. Each patient received an intravenous injection of 100 MBq (2,7 mCi) to 250 MBq (6,8 mCi) of ^{99m}Tc-DTPA. Sequential images were acquired in three phases. The first phase (perfusion) consisted of 30 frames with a duration of 2 seconds each. The second phase (function) included 58 frames with a duration of 30seconds each. The third delayed phase, starting at 80 minutes after tracer injection, was acquired over 180 seconds with a total of 600,000 counts. During the early post-transplant period, no additional hydration was administered to avoid disturbing fluid balance. In later stages, when permitted by the referring physician, 500–600 mL of water was provided orally 30 minutes before imaging. Images were obtained using a gamma camera with a Low Energy High Resolution (LEHR) collimator. The flow and functional phases were evaluated visually, and time-activity curves were generated from regions of interest (ROI) drawn over the graft and the aorta, with background correction applied.

Imaging interpretation. The flow phase was assessed qualitatively, using the aorta or iliac arteries as reference points. Normal renal perfusion was defined as peak kidney activity occurring within 6 seconds of the aortic or iliac peak and reaching equal or higher intensity. Reductions in perfusion were classified as mild, moderate, or severe, based on visual assessment.

The functional phase was evaluated both qualitatively and quantitatively, focusing on:

- accumulation phase (tracer uptake within the first 3 minutes reflecting extraction from blood);
- concentration phase (tubular concentration capacity and water reabsorption);
- and excretion phase (tracer clearance from the collecting system into the bladder).

Based on combined flow and functional findings,

each study was categorized as one of the following: acute rejection (AR), infectious complications (IC), renal vein thrombosis (RVT), urinary fistula (UF), ureteral stenosis (US), or renal artery thrombosis (RAT). Scintigraphy Diagnostic Criteria of the Early Kidney Allograft Complications were following (Table 1) [7, 9, 10].

Table 1

Scintigraphy diagnostic criteria of the early kidney allograft complications

Complication	Perfusion Phase	Functional Phase	Excretion Phase	Typical Scintigraphy Pattern
Acute Rejection (AR)	Moderately to severely decreased perfusion compared to the aorta or previous examination	Reduced tracer uptake; flattened or delayed renogram curve	Poor or delayed excretion into the collecting system and bladder	"Poor flow, poor function"; worsening compared with baseline study
Infectious Complications (IC)	Normal or mildly decreased; possibly focal perfusion defects	Patchy or heterogeneous cortical uptake	Usually normal or mildly delayed	Focal or patchy cortical defects with near-normal perfusion; corresponds to infection sites
Renal Vein Thrombosis (RVT)	Absent or severely reduced perfusion	No cortical tracer retention	No excretion	"No function despite initial blush"
Urinary Fistula (UF)	Normal perfusion	Normal parenchymal function	Normal excretion from the kidney; tracer leakage outside the collecting system	"Normal function with tracer leakage"
Ureteral Stenosis (US)	Normal perfusion	Normal or mildly delayed cortical uptake	Progressive tracer retention in the pelvicalyceal system; delayed drainage to the bladder	"Good function, poor drainage"
Renal Artery Thrombosis (RAT)	Absent perfusion	No cortical tracer uptake	No excretion	"Complete vascular occlusion and graft loss"

Statistical analysis. The data were processed using Statistica v. 10.0 (originally developed by StatSoft Inc., USA) and GraphPad Prism 10.5.0 for Windows (San Diego, CA, USA). The quantitative data were expressed as median and interquartile range, and qualitative parameters – as absolute and relative (%) frequency. The quantitative data were compared by the use of the Mann-Whitney U test (for two unrelated samples), or the Kruskal-Wallis test with the following Dunn`s test for post hoc comparisons (for three unrelated samples). The frequency of binary parameters was compared by the use of Fisher`s exact test (for two unrelated samples), or Fisher`s exact test with Bonferroni correction (for three unrelated samples). A p-value <0,05 was considered statistically significant (considering the Bonferroni correction).

Results. *Clinical characteristics of patients*. A total of 65 patients were included in the study, comprising 32 individuals in the control group (with stable graft function) and 33 patients with allograft complications. There were no significant differences in age or gender distribution between the groups. The median age was 44 (36-51) years in the control group and 45 (35.25-48) years in the complication group (p>0.05). The male-to-female ratio was comparable (14/18 vs. 14/19, respectively; p>0.05). Body mass index (BMI) did not differ significantly between the groups – 26.6 (24.35-28.75) vs. 25.9 (23.83-28.8); p>0.05.

Regarding hematological parameters, white blood cell (WBC) count and erythrocyte sedimentation rate (ESR) showed no significant differences of WBC values – 7.6 (6.2-11.2) vs. 7.95 (7.08-11.63) $\times 10^9$/L; ESR: 22 (20-25) vs. 24 (22-26) mm/h; p>0.05.

However, the platelet (PLT) count was significantly higher in the allograft complication group compared with controls – 264.5 (198.5-303) vs. 209 (167-292) $\times 10^9$/L; p<0.05). Moreover, serum creatinine levels were markedly elevated in patients with allograft complications - 94.65 (78.23-115.1) vs. 76.7 (59.45-86.55) mmol/L; p<0.01), reflecting impaired graft function. The baseline demographic and laboratory characteristics of the two groups are summarized in Table 2.

Table 2

Baseline demographic and laboratory characteristics of the cohort

Parameter	Control group (n=32)	Allograft complications (n=33)	P value
Age	44 (36-51)	45 (35.25-48)	p>0.05
Gender, man/woman	14/18	14/19	p>0.05
BMI	26.6 (24.35-28.75)	25.9 (23.83-28.8)	p>0.05
WBC count, 10^9/L	7.6 (6.2-11.2)	7.95 (7.08-11.63)	p>0.05
PLT count, 10^9/L	209 (167-292)	264.5 (198.5-303)	p = 0.032
ESR, mm/h	22 (20-25)	24 (22-26)	p>0.05
S-Cr, μmol/L	76.7 (59.45-86.55)	94.65 (78.23-115.1)	p = 0.004

Abbreviations: BMI – body mass index; WBC – white blood cell count; PLT – platelet count; ESR – erythrocyte sedimentation rate; S-Cr – serum creatinine.
Data are presented as median and interquartile range.

In summary, while demographic and most hematological parameters were comparable between the groups, a significant increase in platelet count and serum creatinine was observed among patients with allograft complications, suggesting the presence of inflammatory activation and reduced renal function in this cohort.

Scintigraphy evaluation of the short-term complications of the kidney allograft. Analysis of the post-transplant complications. Analysis of post-transplant complications revealed that acute rejection was the most frequent event, occurring in 31% of patients among those with complications. Ureteral stenosis was observed in 22%, and urinary fistula in 16% of cases. Infectious complications were detected in 12% of recipients. Vascular complications were less common, with renal artery thrombosis and renal vein thrombosis occurring in 11% and 8%, respectively. Overall, immunologic and urological complications predominated, while vascular thromboses were though less frequent (Fig. 1).

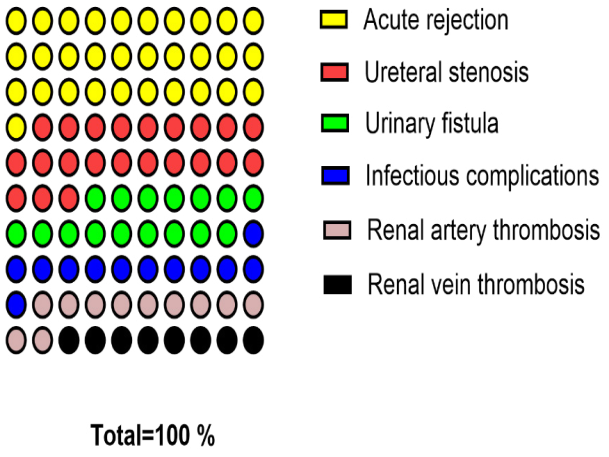

Fig. 1. Distribution of the post-transplant acute complications among examined patients. The figure illustrates the relative frequency (%) of acute complications identified during the early post-transplant period among patients with graft dysfunction.

A total of six major types of kidney allograft complications were identified, each characterized by distinct clinical features. Renal vein thrombosis presented with acute anuria and pain in the transplant area. Acute rejection manifested as a gradual increase in serum creatinine and decreased urine output (oliguria). These findings indicate progressive graft dysfunction due to immune-mediated injury. Infectious complications - all cases were associated with urinary tract infection (UTI), representing the typical infectious process affecting renal allografts. Urinary fistula is characterized by decreased diuresis and fluid collection near the graft site, consistent with urine leakage from the anastomosis or collecting system. Ureteral stenosis demonstrated pyeocaliectasia. Renal artery thrombosis presented with sudden loss of graft function or gradual increase in serum creatinine and hypertension.

Scintigraphy characteristics of the short-term complications of the kidney allograft. The perfusion index (PI) represents the ratio between the early vascular activity of the graft and the total perfusion activity measured in a reference region (commonly the iliac vessels or soft tissue background). It is automatically calculated from time-activity curves obtained during the first 60 seconds after tracer injection. PI was analyzed and compared at the following time points after the transplantation: day 1, day 3, and day 7.

The Function Index (FI) represents the percentage of tracer uptake by the transplanted kidney relative to the total administered dose or to background-corrected reference activity. It provides a quantitative measure of the functional capacity of the allograft. FI was analyzed and compared at the following time points after the transplantation: day 1, day 3, and day 7.

On Day 1, measurements of the PI and FI were obtained in 65 cases to assess vascular and microcirculatory dynamics. The PI was 1.00 (0.92-1.08), and the FI was 0.98 (0.91-1.13) (Fig. 2 A). The glomerular filtration rate (GFR) was evaluated in 65 observations. The GFR level was 55.5 (49.55-61.9) mL/min/1.73 m (Fig. 2 B).

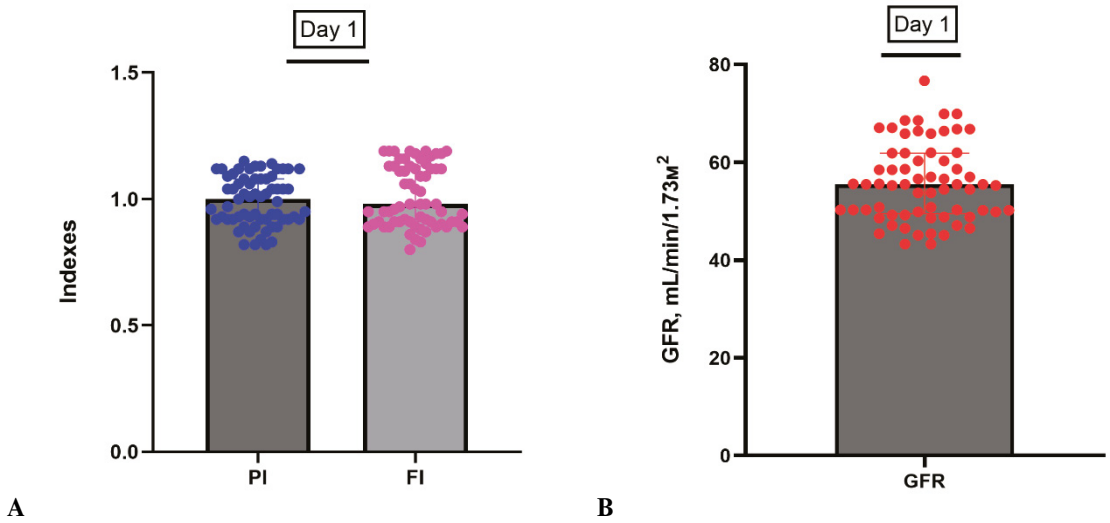

Figure 2. RS parameters of the kidneys' functional capacity in patients after kidney transplantation. (A) – PI and FI indexes. (B) – GFR.

RS indices were analyzed at day 3 and day 7 in patients suspected of various early post-transplant complications. Here we present our findings. For acute rejection, the PI significantly decreased from 0.76 (0.67-0.78) at day 3 after the transplantation to 0.55 (0.47-0.56) ($p<0.0001$) at day 7. In patients with ureteral stenosis, values declined from 0.99 (0.96-1.02) at day 3 to 0.67 (0.62-0.72) ($p<0.0001$) at day 7.

Among those with urinary fistula, the PI did not show any differences between day 3 and day 7 – 1.02 (0.99-1.03) vs. 1.01 (1.00-1.10), respectively ($p>0.05$). This reflects mild hemodynamic stabilization during recovery and absence of further obstruction or ischemia. For infectious complications, values remained relatively stable – 1.09 (1.08-1.12) at day 3 and 1.09 (1.07-1.09) at day 7, respectively ($p>0.05$), suggesting preservation of perfusion despite systemic inflammatory stress.

In contrast, both renal artery and renal vein thrombosis groups exhibited the most pronounced decreases in PI. Values dropped from 0.62 (0.55-0.65) at day 3**,** secondary value 0.32 (0.30-0.38) ($p<0.0001$) at day 7 for arterial thrombosis and from 0.56 (0.55-0.57) at day 3 to 0.39 (0.30-0.40) ($p<0.0001$) at day 7 for venous thrombosis, demonstrating severe impairment of vascular flow consistent with critical ischemic injury (Figure 2). Taken together, these data indicate that SN indexes effectively reflect the hemodynamic consequences of early post-transplant complications (Fig. 3).

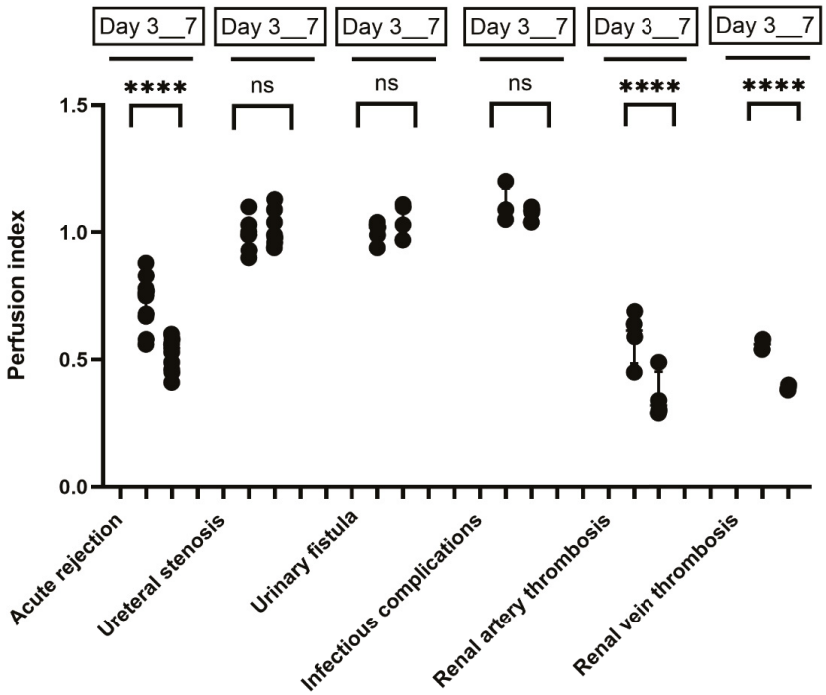

Fig. 3. Dynamics of the PI estimated by RS in patients after the kidney transplantation.

For acute rejection, the FI values were at day 3 - 0.78 (0.75-0.87), with a secondary value at day 7 of 0.50 (0.46-0.52) ($p<0.0001$). Ureteral stenosis demonstrated FI at day 3 at level 0.81 (0.78-0.85) and at day 7, 0.45 (0.38-0.48) ($p<0.0001$).

For urinary fistula, the FI was 1.02 (0.99-1.03) at day 3, with a secondary value of 0.96 (0.93-0.98) at day 7 ($p>0.05$), indicating no significant difference between groups. Infectious complications showed FI at the level of 1.09 (1.08-1.12) and secondary value of 1.03 (1.01-1.05) ($p>0.05$) at day 7.

Vascular complications demonstrated comparatively lower medians. Renal artery thrombosis showed a median FI of 0.69 (0.68-0.70) at day 3 and 0.43 (0.38-0.46) at day 7 ($p<0.0001$). Renal vein thrombosis had FI at level 0.71 (0.68-0.75) at day 3 and secondary value at day 7 - 0.43 (0.43-0.44) ($p<0.0001$) (Fig. 4).

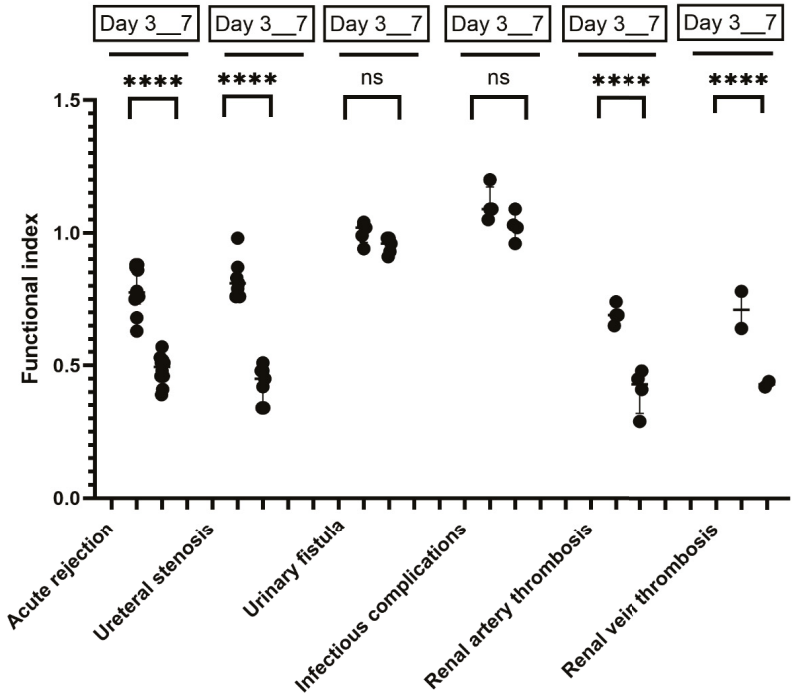

Fig. 4. Dynamics of the FI estimated by RS in patients after the kidney transplantation.

Besides the PI and FI, GFR values were estimated by RS at days 3 and 7 after the kidney transplantation. For acute rejection, the GFR value was 39.5 (27.0-45.3) mL/min/1.73 m^2 at day 3 with a corresponding secondary measure at day 7 – 25.3 (21.1-26.9) mL/min/1.73 m^2 ($p<0.0001$). Ureteral stenosis was demonstrated at day 3 GFR level of 56.8 (55.6-59.5) mL/min/1.73 m^2 and a secondary measure at day 7, 48.6 (46.6-52.4) mL/min/1.73 m^2 ($p<0.0001$).

Urinary fistula had GFR at level 50.8 (47.7-53.2) mL/min/1.73 m^2 at day 3 with a secondary value of 50.3 (46.5-52.7) mL/min/1.73 m^2 at day 7. For the infectious complications group, GFR was 54.5 (48.7-55.5) mL/min/1.73 m^2 at day 3, and the secondary measure was 52.3 (44.8-55.0) mL/min/1.73 m^2 at day 7 ($p > 0.05$).

Vascular complications demonstrated lower GFR values. Renal artery thrombosis presented GFR at level 49.3 (45.9-51.8) mL/min/1.73 m^2 at day 3 with a secondary measure of 39.4 (37.6-40.7) mL/min/1.73 m^2 at day 7 ($p<0.0001$). Renal vein thrombosis had a GFR at level 39.3 (39.0-39.7) mL/min/1.73 m^2 at day 3 and a secondary measure of 32.9 (31.7-34.2) mL/min/1.73 m^2 at day 7 ($p<0.001$) (Fig. 5).

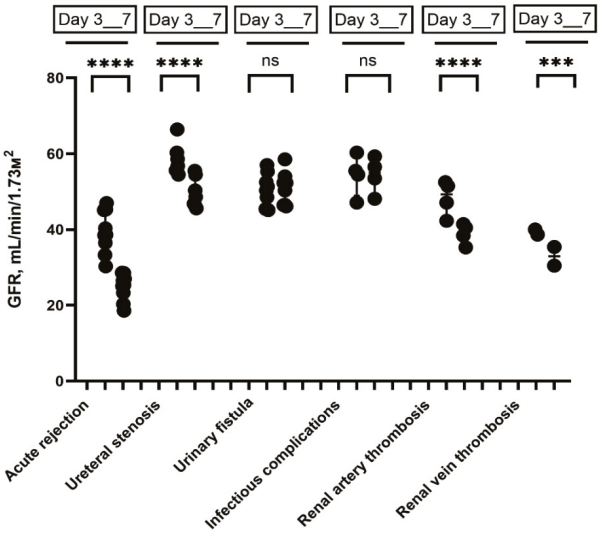

Fig. 5. Dynamics of the GFR estimated by RS in patients after the kidney transplantation.

Peculiarities of the ultrasound evaluation of post-transplant complications. In parallel with scintigraphy studies, US examination was performed in all 65 pa-

tients to evaluate graft morphology, vascular flow, and the presence of early post-transplant complications. Gray-scale and Doppler ultrasonography are used for imaging of graft perfusion and structural integrity.

In the control group with stable graft function, the grafts demonstrated normal morphology with homogeneous parenchymal echogenicity, preserved corticomedullary differentiation, and normal vascular patterns. The resistance index (RI) in these patients was 0.71 (0.68-0.75), consistent with normal perfusion and low intrarenal vascular resistance for the transplant. Among the 33 patients with allograft complications, distinct sonographic findings were recorded at day 7 but not day 3, depending on the underlying pathology.

Acute rejection presented with increased cortical echogenicity and loss of corticomedullary differentiation in 90% of cases. The kidneys were enlarged in 80% cases, with a value RI of 0.88 (0.83-0.91) ($p<0.001$ vs. controls). Doppler flow analysis revealed decreased diastolic flow and elevated systolic-to-diastolic ratio (S/D>3.0), consistent with increased vascular resistance due to immune-mediated parenchymal edema.

Ureteral stenosis in gray-scale imaging revealed pelvicalyceal dilatation in all affected patients, with preserved cortical thickness. The RI was at level 0.89 (0.77-0.82), higher than in controls ($p<0.001$), reflecting mild post-obstructive resistance. In urinary fistula cases, anechoic peri-graft fluid collections were detected adjacent to the lower pole or near the ureterovesical junction. The parenchymal echotexture remained preserved, and RI values were shown within the normal range – 0.74 (0.71-0.76).

Infectious complications developed typically due to UTI. The kidneys demonstrated increased cortical echogenicity and blurred corticomedullary differentiation in 75% cases. The RI value was 0.77 (0.75-0.80) ($p>0.05$ vs. controls).

In patients with renal artery thrombosis, color Doppler showed absent arterial flow within the graft and a high-resistance (RI>0.95) in the proximal segment. Kidneys appeared enlarged and hypoechoic, consistent with acute ischemia. Renal vein thrombosis demonstrated absent venous flow and reversal of diastolic flow in the intrarenal arteries. Patients had severe graft swelling and RI>0.95, corresponding to venous congestion and acute graft failure (Table 3).

Table 3

Summary of RI values in examined patients at day 7 after the transplantation

Group	Median RI [IQR]	Significance vs. Control
Control	0.71 (0.68-0.75)	-
Acute rejection	0.88 (0.83-0.91)	p<0.001
Ureteral stenosis	0.89 (0.77-0.82)	p<0.001
Urinary fistula	0.74 (0.71-0.76)	p>0.05
Infectious complications	0.77 (0.75-0.80)	p>0.05
Renal artery/vein thrombosis	> 0.95	-

Discussion. In this study, we evaluated the clinical, laboratory, scintigraphy and ultrasonographic parameters in kidney transplant recipients with and without early post-transplant complications. Our results demonstrate that demographic and general hematological characteristics did not significantly differ between the groups (controls and groups with early graft complications). Patients with allograft complications exhibited higher platelet counts and elevated serum creatinine levels. These changes are direct signs of ongoing inflammatory activation and impaired renal function. It was shown previously that elevated platelet counts are associated with endothelial dysfunction and immune-mediated injury during graft rejection and other inflammatory processes, reflecting their role in microvascular disturbances and thrombogenic potential within the transplanted organ [**10**].

The ultrasound evaluation, performed in parallel with scintigraphy studies, provided additional real-time morphological and hemodynamic data. In the control group with stable graft function, gray-scale and Doppler ultrasonography demonstrated normal graft morphology with homogeneous echogenicity, preserved corticomedullary differentiation, and normal vascular flow patterns. The RI of 0.71 (0.68-0.75) was consistent with normal perfusion and low intrarenal resistance. These confirm sufficient allograft function.

Among patients with early post-transplant complications, certain sonographic patterns were observed according to the underlying pathology. Acute rejection was characterized by increased cortical echogenicity, loss of corticomedullary differentiation, and mild graft enlargement in most cases. The RI shown pronounced elevation accompanied by decreased diastolic flow and a high systolic-to-diastolic ratio (S/D>3.0). These changes reflect increased vascular resistance due to immune-mediated parenchymal edema and microcirculatory disorders. In patients with ureteral stenosis,

pelvicalyceal dilatation with a moderately increased RI was found. These changes indicate post-obstructive hemodynamic stress [11].

In contrast, the urinary fistula presented as anechoic peri-graft fluid collections adjacent to the ureterovesical junction, accompanied by normal parenchymal architecture and near-normal RI values. Localized leakage without perfusion compromise was detected in this group. Infectious complications showed only mild cortical echogenicity and a slight RI increase. These findings reflect limited parenchymal involvement. In vascular complications, i.e., renal artery or vein thrombosis, Doppler findings were dramatic – absent flow signals, high RI, and marked graft swelling. These sonographic patterns were detected at day 7 after the transplantation was performed.

The scintigraphy evaluation provided complementary quantitative insights into the hemodynamic and functional status of the transplanted kidneys. The key point is that RS changes were documented at an early stage after the transplantation (day 3). Among the spectrum of early post-transplant complications, acute rejection was the most prevalent. Next were ureteral stenosis and urinary fistula. Our findings are in line with previous studies and emphasize the predominance of immunologic and urological complications during the early post-transplant period. At the same time, vascular thromboses is less common event.

Dynamic renal scintigraphy parameters - perfusion index, function index and glomerular filtration rate proved to be sensitive indicators of allograft dysfunction. In the control group, PI and FI values were close to normal ranges. This suggests preserved perfusion and function of the kidneys. In contrast, both acute rejection indices declined significantly between days 3 and 7.

In ureteral stenosis, both PI and FI decreased, indicating that obstructive processes not only change urine flow. However, obstruction also leads to a reduction in renal blood flow and tracer uptake. Urinary fistula and infectious complications were associated with relatively stable scintigraphy and sonographic parameters, meaning the predominance of localized structural or inflammatory processes without perfusion loss.

Vascular complications, renal artery and vein thrombosis, showed the most dramatic alterations detected with both methods. Absent or reversed flow on Doppler US and markedly reduced PI, FI, and GFR on scintigraphy were found. This is consistent with an acute decrease in perfusion and severe ischemic injury.

To summarize, we observed decreases in perfusion index (PI) and function index (FI) across different categories of early post-transplant complications. Our findings reflect distinct mechanisms of graft injury. In acute rejection, we hypothesize the presence of immune-mediated endothelial activation, interstitial edema, and microvascular inflammation, which in turn increase intrarenal vascular resistance, leading to reduced arterial inflow and impaired capillary perfusion, which is captured cartographically as a decline in PI.

Simultaneously, inflammatory damage to tubular and glomerular structures compromises tracer extraction and cortical uptake, resulting in a marked reduction in FI. In ureteral stenosis, the initial perfusion is relatively preserved. However, progressive intrapelvic pressure and post-obstructive vasoconstriction reduce renal blood flow and parenchymal function over time, explaining the delayed but significant decrease in both PI and FI [7-9].

Urinary fistula and infectious complications primarily represent localized extrarenal leakage or focal inflammatory processes without substantial compromise of global graft perfusion or tubular function, which accounts for the relative stability of scintigraphy indexes in these groups [8, 9]. Vascular complications, including renal artery and vein thrombosis, cause abrupt and severe interruption of blood flow or venous outflow obstruction, leading to profound ischemia, congestion, and loss of parenchymal viability. Therefore, PI and FI show the most pronounced and rapid declines. Taking together our results, these patterns demonstrate that changes in PI and FI are not merely descriptive but reflect specific hemodynamic and functional consequences of different early allograft complications [10-12].

To summarize, our results confirm that scintigraphy indexes (PI, FI, GFR) provide a comprehensive early assessment of graft perfusion, structure, and function. Accurate monitoring of these parameters enables early differentiation among various types of complications in patients after kidney transplantation. Further studies with larger cohorts and long-term follow-up are needed to validate diagnostic algorithms and to set up thresholds for predicting graft complications evaluation.

Several limitations of this study should be mentioned. First, this was a single-center observational study with a relatively modest sample size, which may limit the generalizability of the findings. The study was exploratory in nature, and no sample size calculation was performed. Consequently, formal diagnostic accuracy analyses, including ROC/AUC estimation, could not be conducted and planned for further investigations. Finally, the study focused on early post-transplant changes and did not include long-term follow-up or outcome-based validation of imaging findings. Future prospective, multicenter studies with quantitative thresholds and longitudinal follow-up are warranted to confirm and extend our results.

Conclusions:

1) Acute rejection was the most frequent early post-transplant complication (31%), followed by ureteral stenosis (22%) and urinary fistula (16%). Infectious complications and vascular thromboses were less common.
2) Patients with early allograft complications exhibited significantly higher serum creatinine and platelet counts compared to the control group, reflecting impaired renal function and inflammatory activation.

3) Doppler and gray-scale ultrasonography effectively detected morphological and hemodynamic changes associated with different complications at a later time-point (day 7) as compared to RS.
4) Renal Scintigraphy provided early (day 3) sensitive quantitative assessment of graft perfusion (PI), function (FI), and filtration (GFR) at early time points (day 3 and 7).
5) Acute rejection and ureteral stenosis were associated with significant reductions in PI, FI, and GFR, whereas urinary fistula and infectious complications showed stable indexes. Vascular thromboses exhibited the most pronounced decreases, confirming severe perfusion impairment.
6) RS indices can be used as a precise method for the early evaluation of graft dysfunction, therefore making it possible to avoid invasive procedures such as biopsy, which is critically important during the early post-transplant period.

Acknowledgement. The corresponding author gratefully acknowledges colleagues from Bogomolets National Medical University for their support and collaboration.

Conflict of interest. The author declares no conflict of interest.

Funding source. This work was done without finding support.

References:

1. *Mirasol J, Choksi A.* End-stage renal disease and renal transplantation. Physician Assistant Clinics.2025;10(3):513-532. doi: 10.1016/j.cpha.2025.01.010.
2. *Elizer S, Mantell BS.* Risk factors affecting mortality in pediatric heart transplantation: A comprehensive review of pre- and post-transplant contributors. JHLT Open. 2025;9:100309. doi: 10.1016/j.jhlto.2025.100309.
3. *Lee PH, Huang SM, Tsai YC, Wang YT, Chew FY.* Biomarkers in contrast-induced nephropathy: Advances in early detection, risk assessment, and prevention strategies. Int J Mol Sci. 2025;26(7):2869. doi: 10.3390/ijms26072869.
4. *Ettenger RB, Seifert ME, Blydt-Hansen T, Briscoe DM, Holman J, Weng PL, et al.* Detection of subclinical rejection in pediatric kidney transplantation: Current and future practices. Pediatr Transplant. 2024;28(6):e14836. doi: 10.1111/petr.14836.
5. *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.
6. *Rodgers SK, Sereni CP, Horrow MM.* Ultrasonographic evaluation of the renal transplant. Radiol Clin North Am. 2014;52(6):1307-24. doi: 10.1016/j.rcl.2014.07.009.
7. *Anand Kumar R, Maran T, Davidson J, Hassan I.* Nuclear medicine imaging findings in end-stage renal disease and renal transplant complications Clin Radiol. 2023;78(5):333-339. doi: 10.1016/j.crad.2022.12.004.
8. *Belhoste M, Allenbach G, Agius T, Meier RPH, Venetz JP, Corpataux JM, et al.* Role of post-transplant graft scintigraphy in kidney donation after circulatory death. Front Transplant. 2022;1:1065415. doi: 10.3389/frtra.2022.1065415.
9. *Benjamens S, Berger SP, Glaudemans AWJM, Sanders JSF, Pol RA,* Slart RHJA. Renal scintigraphy for post-transplant monitoring after kidney transplantation. Transplant Rev (Orlando).2018;32(2):102-109. doi: 10.1016/j.trre.2017.12.002.
10. *Kohli R, Platton S, Forbes S, Thuraisingham R, Tan J, Green L, MacCallum P.* Renal transplant and hemostasis: Early postoperative changes in recipients and donors. Res Pract Thromb Haemost.2023;7(4):100168. doi: 10.1016/j.rpth.2023.100168.
11. *Buckley AR, Cooperberg P, Reeve C, Magil A.* The distinction between acute renal transplant rejection and cyclosporine nephrotoxicity: Value of duplex sonography. Am J Roentgenol.1987;149(3):521-525. doi: 10.2214/ajr.149.3.521.
12. *Sfakianaki E, Sfakianakis GN, Georgiou M, Hsiao B.* Renal scintigraphy in the acute care setting. Semin Nucl Med.2013;43(2):114-28. doi: 10.1053/j.semnuclmed.2013.01.001.
13. *Ghonge NP, Goyal N, Vohra S, Chowdhury V.* Renal transplant evaluation: Multimodality imaging of post-transplant complications. Br J Radiol.2021;94(1124):20201253. doi: 10.1259/bjr.20201253.