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The role of dynamic angionephroscintigraphy in the diagnosis of urinary tract incompetence after kidney transplantation

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Abstract

Introduction. *The urinary tract incompetence ("extravasation of urine") of the renal allograft is the most common urological complication in the early postoperative period.*

The purpose *was to evaluate the efficacy of the dynamic angionephroscintigraphy technique in diagnosing the extravasation of urine after kidney transplantation.*

Material and methods. *The results of dynamic angionephroscintigraphy were analyzed for the purpose of verifying/diagnosing the extravasation*

of urine in 63 patients who underwent kidney transplantation at N.V.Sklifosovsky Research Institute for Emergency Medicine in 2019. Dynamic angionephroscintigraphy of the renal allograft was performed with the glomerulotropic ^{99m}Tc-pentatech radiopharmaceutical on a two-detector single-photon emission tomography "Infinia II" and a combined CT SPECT / CT system "Discovery NM/CT670".

Results. *The sensitivity of dynamic angionephroscintigraphy in detecting the extravasation of urine was 100%, the specificity was 88%, and the accuracy of the method was 89%.*

Conclusion. *Dynamic angionephroscintigraphy is a highly sensitive and specific method for diagnosing the extravasation of urine after kidney transplantation.*

Keywords: dynamic angionephroscintigraphy, kidney transplantation, urinary tract failure

Conflict of interests Authors declare no conflict of interest

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CUSM, congenital urinary system malformations

DANSG, dynamic angionephroscintigraphy

TN, true negative

TP, true positive

FN, false negative

FP, false positive

SPECT / CT, single photon emission computed tomography with computed tomography

RAG, renal allograft

RPH, radiopharmaceutical

US, ultrasound examination/ ultrasonography

CRF - chronic renal failure

^{99m}Tc-DTPA, ^{99m}technetium diethylenetriaminepentaacetate

Introduction

One of the most common urological complications after kidney transplantation is the failure of the renal allograft (RAG) urinary tract. In fact, this name hides a number of complications that can be united considering a similar clinical presentation and, often, by therapeutic tactics; these complications can develop as a result of different causes and at different levels of the urinary tract, either at the level of the pelvis or directly the donor organ ureter, or in the area of the urinary anastomosis, or even recipient's bladder. The incidence of such complications, commonly referred to as "the exravasation of urine" for short, amounts to 1-3% of all kidney transplants [1, 2]. Most often, the failure develops in the area of neoureterocystoanastomosis, as a result of impaired blood supply and necrosis of the distal part of the RAG ureter, technical errors, infection or mechanical causes, for example, as a result of an overfilled bladder with a tear in its mucous membrane with ineffective catheterization or breaking the urination regimen.

Failure usually develops early after surgery and can cause a variety of clinical manifestations. So, if the extravasation of urine develops against the drained RAG bed, it is characterized by an abrupt decrease in diuresis and a significantly increased amount of discharge through the safety drainage. No pronounced painful sensations usually occur in the

RAG recipient, the complication can be recognized by the characteristic clinical presentation and confirmed by the results of biochemistry study of the drained discharge proving its nature. If the safety drainage has been already removed by the moment of the extravasation of urine development, a suddenly developing pronounced pain syndrome in the recipient comes ahead in the clinical pattern of the complication. In this case, urgent ultrasonography (US examination) and dynamic angionephroscintigraphy (DANSG) of the graft are used. If a fluid collection is detected in the RAG bed and the clinical picture is questionable, it is possible to perform a puncture of the collection for the purpose of differentiated diagnosis and determination of treatment tactics, to clarify the nature of the contents.

Currently, there is insufficient evidence for the benefits of DANSG or ultrasound in the diagnosis of urological complications. Ultrasound has been the most available, but the operator-dependent method: the interpretation of data is largely associated with the ability and skills of the doctor and, as a rule, is used as the first method of diagnosis [3]. DANSG is a study that provides information about the graft position, its blood supply, filtration-excretory function, and the passage of the labeled urine in the urinary tract. In case of the extravasation of urine, DANSG can determine the location (level), direction, and prevalence of abnormal urine extravasation, which can play an important role in assessing damage, especially with inconclusive clinical and laboratory data [4]. At early stages, both methods can not differentiate the nature of the pathological fluid collection, which is necessary for the choice of treatment tactics. Stan Benjamens and colleagues from the University of Groningen (Netherlands), referring to the studies of transplantologists from Greece and Turkey, on the basis of 965 cases of 1,525 kidney transplant recipients, where the frequency of urinary congestion was 1.5–

1.6%, noted the feasibility of using DANSG with ^{99m}Tc-DTPA in combination with routine monitoring [5-7]. A study by other authors [8] using DANSG with ^{99m}Tc-DTPA revealed 12 (of 133 examined patients) cases of the extravasation of urine, without any false-negative or false-positive results.

This study was performed to assess the diagnostic significance and, accordingly, the efficacy of DANSG for cases of suspected extravasation of urine in the clinical practice of N.V.Sklifosovsky Research Institute for Emergency Medicine.

The study purpose was to evaluate the efficacy of the DANSG method in the diagnosis of the extravasation of urine after kidney transplantation.

The objectives were to assess the sensitivity, specificity, accuracy, and predictive value of positive and negative results of DANSG in the diagnosis of the extravasation of urine after kidney transplantation.

Material and methods

The study was based on a retrospective analysis of the results obtained from RAG DANSG performed in 63 patients at early stages after cadaveric kidney transplantation performed at N.V.Sklifosovsky Research Institute for Emergency Medicine in the period from January to December 2019. All kidney transplantation operations were performed as standard, and the donor ureter was anastomosed with recipient's bladder to restore the urinary tract. The total number of kidney transplants performed in 2019 was 230. The criterion for inclusion of recipients in the study was all cases of DANSG performed to assess the perfusion and the RAG secretory-excretory function, as well as the cases of suspected

failure of the graft urinary tract. Characteristics of RAG recipients in the study group are presented in Table 1.

Table 1. Characteristics of renal allograft recipients

Parameters		Number of recipients in the study group
Male, % (n) Female, % (n)		57.1 (36) 42.9 (27)
Age, years, M (25–75%)		50 (42; 56)
Body Mass Index (BMI), m (25–75%) (min, max)		24.5 [21.3;26.8] 17.9-36.8
CRF etiology	Chronic glomerulonephritis	49.2 (31)
	Type 2 diabetes mellitus	9.5 (6)
	Polycystic kidney disease	7.9 (5)
	Systemic diseases	7.9 (5)
	Others	7.9 (5)
	CUSM	6.4 (4)
	Chronic pyelonephritis	6.4 (4)
	Hypertension disease	4.8 (3)

Note: CRF, chronic renal failure; CUSM, congenital urinary system malformations

To determine the sensitivity and specificity of the DANSG method, based on the conclusions, the following concepts were introduced:

- *True-positives* (TP) mean correctly classified positive cases of the extravasation of urine;
- *True-negatives (*TN) mean correctly classified negative cases of the extravasation of urine;
- *False-negatives (FN*) mean positive cases of the extravasation of urine classified as negative (type I error);
- *False-positives (F*P) mean negative cases of the extravasation of urine classified as positive (type II error).

Investigation: DANSG was performed on a two-detector single-photon emission tomography "Infinia II" and a combined system of

single-photon emission computed tomography/computed tomography (SPECT/CT) “Discovery NM/CT 670” using the glomerulotropic ^{99m}Tc-pentatech radiopharmaceutical (RPH) ^{99m}Tc-pentatech (^{99m}Tc-DTPA, the administered dose of 120-150 MBq, radiation exposure of 0.6–0.8 mSv). The analysis of the obtained data allowed us to trace the RPH passage through the urinary tract and identify the extravasation of urine due to tits failure. In addition, it is important that the renal graft perfusion (assessed by Hilson perfusion index) and glomerular filtration rate (GFR) were simultaneously evaluated. We also calculated separately the contributions of the filtration and excretory segments of the renogram, the time of RPH maximum absorption and half-life (T_{max} and $T_{1/2}$) in a parenchymal renogram. Additionally, the filtration index (the degree of amplitude increment at 2-3 min of the ascending renogram section), the coefficient of RPH capture by the organ parenchyma (the ratio of kidney/background accumulation at the peak of the curve and at minute 20), the excretion coefficient (the ratio of RPH accumulation in the bladder to that in the RAG at minute 20), and the time of RPH appearance in the bladder were determined.

Statistical analysis: to assess the sensitivity and specificity of the method, we used mathematical formulas for calculating the desired parameters and constructing the ROC curve in the IBM SPSS V26 software.

Results and discussion

The study included patients of different age (from 31 to 77 years old) (Table 1). There were 14.2% more men than women in the study. Chronic glomerulonephritis was the most common disease (49.2%) leading to end-stage CRF. For the purpose of immunosuppressive therapy, a three-component regimen was used in all patients: tacrolimus,

mycophenolic acid, prednisolone in 66.6% of patients (n=42); cyclosporine, mycophenolic acid, prednisolone in 33.3% (n=21). Induction of immunosuppression to prevent acute rejection was performed with basiliximab in 79.4% (n=50) of RAG recipients, and antithymocyte immunoglobulin in 20.6% (n=13).

If the extravasation of urine was suspected, all the patients underwent ultrasound, DANSG, and biochemical analysis of the discharge from the drainage tube. The experience of performing DANSG made it possible to change the protocol scheme in patients with suspected extravasation of urine. If during the dynamic recording (20 min), the extraorgan RPH entry was not convincing, but the clinical and ultrasound findings indicated a high probability of extravasation of urine, DANSG was supplemented with a delayed imaging (static frames) and tomographic sections (SPECT) at 30 min–6 hours after the start of the study. During this time, the intensity of RPH accumulation and pathological spread (entry outside the organ) increased, which improved visualization and made it possible to confirm the extravasation of urine. An example of DANSG demonstrating the extravasation of urine in Patient S., 45 years old, is shown in Fig. 1-4.

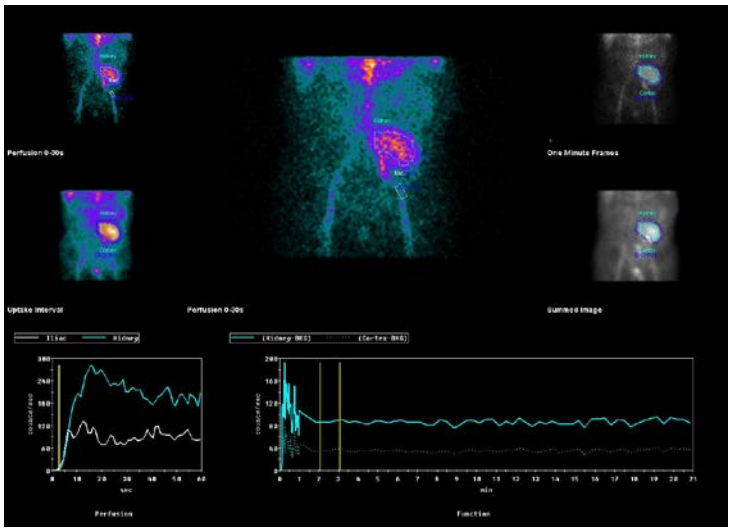

Fig. 1. Dynamic angionephroscintigraphy of patient S., 45 years old. During the first 20 minutes of dynamic recording: satisfactory perfusion of the renal allograft, an impaired filtration-excretory function. No extraorganic intake of the radiopharmaceutical was detected

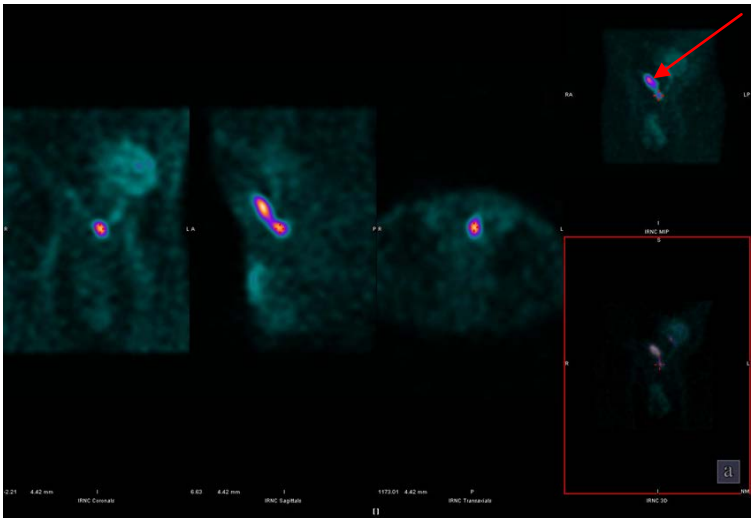

Fig. 2. Delayed image of the graft (after 30 min) of patient S., 45 years old: one cut in 3 planes of the single-photon emission computed tomography mode. Scintigraphic signs of the extravasation of urine; the arrow indicates the area of the radiopharmaceutical distribution outside the ureter

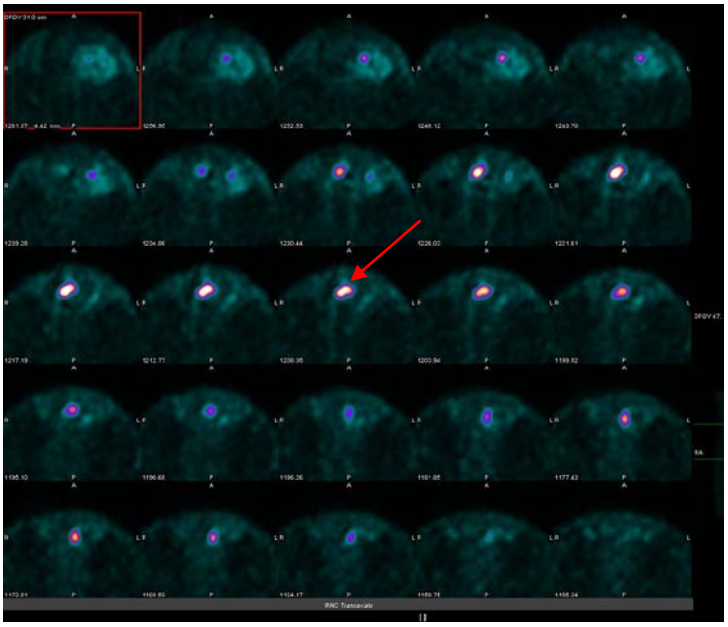

Fig. 3. Delayed image (after 30 min) of patient S., 45 years old: a series of images in the transversal plane of the single-photon emission computed tomography mode. Scintigraphic signs of the extravasation of urine; the arrow indicates the spread of the radiopharmaceutical outside the ureter

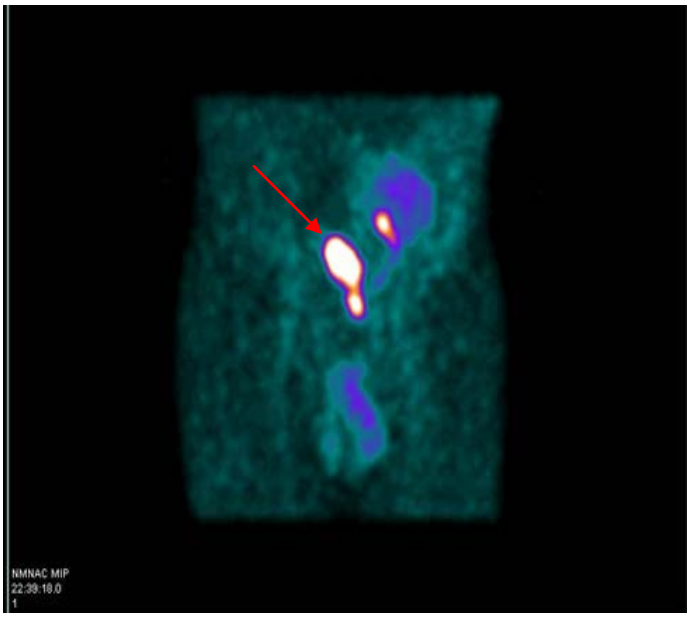

Fig. 4. Delayed image (after 2 hours) of patient S., 45 years old in a static mode. Scintigraphic signs of the extravasation of urine; the arrow indicates the area of increased intensity of extraorganic radiopharmaceutical accumulation (the area of extravasation)

According to the DANSG results, the diagnosis of the extravasation of urine was made in 13 of 63 patients. In this group, the extravasation of urine was confirmed in 6 cases at surgery (true-positive results); and in 7 cases, the abnormal accumulation of RPH was associated with other processes in the examined area: hematomas were revealed in three patients, lymphocele in three, and hydronephrosis was diagnosed in one case in the presence of extended stenosis of the ureter with a pronounced retention of the radiopharmaceutical in suprastenotic region (false-positive results), which was mistaken for minimal extravasation of urine. In 2 patients with hematomas, the wound revision was performed, followed by hematoma removal; in 3 patients with lymphocele and one patient with hematoma, conservative tactics were chosen. A patient with hydronephrosis in the presence of extended ureteral stenosis was operated on (reconstructive surgery was performed).

To verify the DANSG result confirming the extravasation of urine, a biochemical analysis of the fluid entering through drainage or obtained during puncture from the RAG bed was repeated. During the wound revision, a visual assessment of urinary tract damage was performed (for example, when the anastomosis failed as a result of necrosis of the distal part of the ureter) (Fig. 5). The incidence of the extravasation of urine in kidney transplantation in 2019 was 2.6% (n=6). The results of DANSG are presented in Table 2.

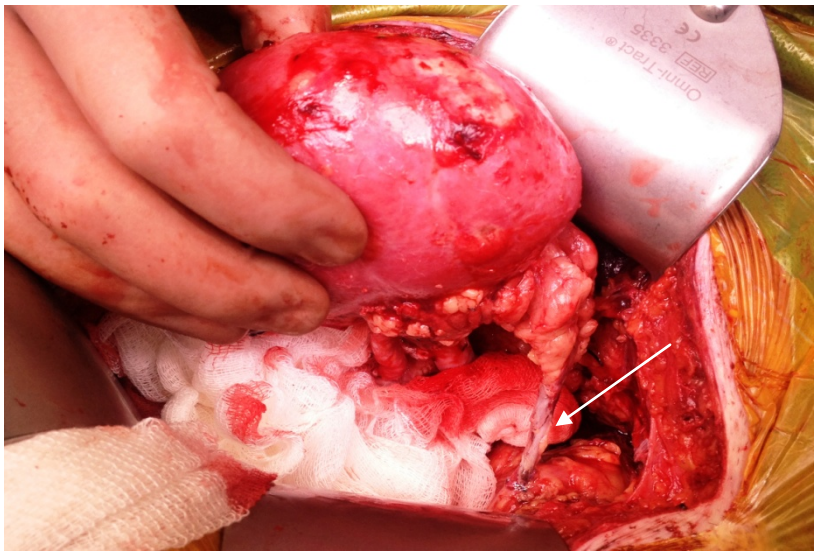

Fig. 5. Necrosis of the distal and middle part of the ureter with the development of the extravasation of urine – the wound revision. The arrow indicates the necrotic part of the ureter

Table 2. Distribution of renal allograft recipients according to the dynamic angionephroscintigraphy results

Result of RAG DANSG	Extravasation of urine (clinical pattern, biochemistry)	
	Present	Absent
Positive	TP 6	FP 7
Negative	FN 0	TN 50

Thus, the diagnostic value of DANSG had the following the parameters: Se (sensitivity) 100%, Sp (specificity) 88%, Ac (accuracy) 89%; the predictive value of a positive result made 46%, and the predictive value of a negative result was 100%.

To characterize the DANSG method, we grouped the obtained data of the RAG DANSG method according a 5-point scale, where 1 denoted the extravasation of urine being absolutely absent, 2 denoted the extravasation of urine being probably absent, 3 meant an equally probable

presence or absence of the extravasation of urine, 4 meant a probable presence of the extravasation of urine, and 5-meant a definite presence of the extravasation of urine. Table 3 shows the categories of RAG DANSG conclusions compared to the true diagnosis.

Table 3. Distribution of patients by categories of dynamic angionephroscintigraphy conclusions

Actual state	Categories of decisions					Total
	1	2	3	4	5	
Extravasation of urine is present	0	0	1	3	2	6
No extravasation of urine	50	0	2	3	2	57

Based on the results of analyzing the DANSG data, the ROC curve was plotted, shown in Fig. 6. Based on the nature of the ROC curve, we can state that DANSG is a highly informative method with a high sensitivity and specificity for diagnosing the extravasation of urine.

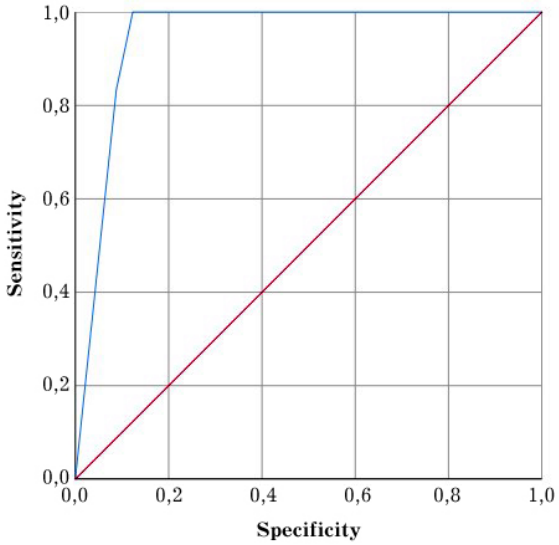

Fig. 6. Roc-curve, a characteristic curve for the dynamic angionephroscintigraphy method

Radionuclide technique of dynamic angionephroscintigraphy with ^{99m}Tc-pentatechom (^{99m}Tc-DTPA) plays an important role in the diagnosis of the extravasation of urine in patients after kidney transplantation, demonstrating a high sensitivity (100%). The difficulties of a differentiated diagnosis of fluid collections (extravasation of urine, hematoma, lymphocele) by using the radionuclide method have been reflected in the specificity (88%) and accuracy (89%) parameters.

Conclusions

1. The method of dynamic angionephroscintigraphy is effective in diagnosing the extravasation of urine after kidney transplantation.

2. The parameters of diagnostic significance of dynamic angionephroscintigraphy were as follows: Se (sensitivity) 100%, Sp (specificity) 88%, Ac (accuracy) 89%, the predictive value of a positive result made 46%, and the predictive value of a negative result was 100%.

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