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THE ROLE OF RENAL VASCULAR DOPPLEROGRAPHY IN THE DIAGNOSIS OF CHRONIC KIDNEY DISEASE

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Annotation. *This article presents materials devoted to the study of the relationship between the resistance indices (RI) of the main and intraparenchymatous renal arteries and clinical and laboratory parameters, as well as determining their prognostic significance in assessing the progression of chronic kidney disease (CKD) in patients with glomerular or interstitial diseases.*

Key words: *chronic kidney disease, ultrasound dopplerography, resistance index.*

РОЛЬ ДОППЛЕРОГРАФИИ СОСУДОВ ПОЧЕК В ДИАГНОСТИКЕ ХРОНИЧЕСКОЙ БОЛЕЗНИ ПОЧЕК

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Аннотация. *В данной статье представлены материалы посвященные изучению взаимосвязи индекса резистентности (ИР) магистральных и интрапаренхиматозных почечных артерий и клинико–лабораторных параметров, а также определение их прогностической значимости в оценке прогрессирования хронической болезни почек (ХБП) у больных гломерулярным или интерстициальными болезнями.*

Ключевый слова: *хроническая болезнь почек, ультразвуковая допплерография, индекс резистентности.*

СУРУНКАЛИ БУЙРАК КАСАЛЛИГИНИ ТАШҲИСЛАШДА БУЙРАК ТОМИРЛАРИ ДОППЛЕРОГРАФИЯСИНИНГ АҲАМИЯТИ

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Аннотация. *Ушбу мақолада гломеруляр ва интерстициал касалликларга чалинган беморларда асосий ва интрапаренхиматоз буйрак артерияларининг резистентлик индекси (РИ) ва клиник–лаборатор кўрсаткичлар параметрлари ўртасидаги боғлиқликни ўрганишга, шунингдек, сурункали буйрак касаллиги (СБК) ривожланишини баҳолашда уларнинг прогностик аҳамиятини аниқлашга бағишланган материаллар келтирилган.*

Калит сўзлар: *сурункали буйрак касаллиги, ултратовушли допплерография, резистентлик индекси.*

The high standardized mortality rate in patients with chronic kidney disease – CKD (70 per 1000 patients) necessitates continuous improvement of approaches to detecting signs of kidney damage in its early stages [23]. Modern diagnosis of CKD includes the following parameters: glomerular filtration rate (GFR), albuminuria/proteinuria, changes in urine sed-

iment and electrolyte balance due to tubule damage, nephrobiopsy data, a history of transplantation, as well as features of changes in kidney structure and size according to ultrasound [4,6,15]. However, in the initial diagnosis of CKD, these data do not allow us to accurately characterize the severity of kidney damage and the degree of nephrosclerosis, especially since it is not always possible to perform a kidney biopsy for this purpose. In this regard, the search for clinical and laboratory factors of an unfavorable prognosis of CKD is justified.

According to a number of studies, these include the age of the patient, the severity of proteinuria (PU), a decrease in GFR, and the presence of arterial hypertension (AH) [3,14,15]. In addition, a violation of intrarenal hemodynamics makes a great contribution to the progression of CKD. One of the visual assessment methods that allows us to characterize the features of intrarenal blood flow is ultrasound Dopplerography (USDG) of the renal vessels, which allows us to determine calculated indices, in particular the resistance index (RI), which reflects the resistance of the muscular layer of the vessel wall.

The aim. To study the relationship of resistance indices (RI) of the main and intraparenchymatous renal arteries and clinical and laboratory parameters, as well as to assess their prognostic significance in assessing the progression of chronic kidney disease (CKD).

Materials and methods. The study included 110 patients with signs of CKD who were hospitalized in the Department of Nephrology of the National Medical Center of the Republic of Uzbekistan in the period from March 2023 to October 2024. The patients were divided into two groups with glomerular or interstitial diseases. Among them, 52 (47.2%) women and 58 (52.8%) men; the average age was 45.4±12.6 years. All patients were divided into two groups comparable in number: 54 with a predominance of glomerular pathology (chronic glomerulonephritis – CGN) and 56 with tubulo–interstitial lesions, in particular, 19 patients suffered from tubulo–interstitial nephritis (TIN), 10 – chronic pyelonephritis, 15 – kidney damage associated with hypertension, 12 – with antiphospholipid syndrome, the remaining ones are polycystic kidney disease. During hospitalization, the clinical, instrumental and laboratory data of patients were analyzed: age, daily PU, GFR (calculated using the CKD–EPI formula), systolic and diastolic blood pressure, pulse pressure (PD), RI according to ultrasound data.

Standard ultrasound, ultrasound was performed on all 110 patients on an ultrasound device of the expert class Sonoline Antares (Siemens Medical Solutions) using a sensor with a frequency of 1–5 MHz. The length and transverse size of the kidneys, the thickness of the renal parenchyma were measured, followed by the calculation of the average values. The parenchymopyelic index (PPI) was calculated as the ratio of the size of the parenchyma to the size of the central echo complex, which includes the calyx–pelvic system with adipose tissue, blood and lymph vessels [1]. RI is the ratio of the difference between the maximum systolic velocity and the final diastolic velocity to the maximum systolic velocity, determined for the renal artery (RA), interlobular arteries (IA) and the renal arc arteries. For a comparative analysis of the correlation in independent samples between quantitative data, the Pearson criterion was used (where $p<0.05$ was evaluated as a statistically significant result). When calculating the correlation coefficients, the average value of the renal artery RI was taken based on the fact that this indicator varies slightly between organs [7].

To assess the prognostic significance of RI of RA, segmental arteries (SA) and IA, their sensitivity and specificity, ROC analysis was used with the construction of curves of the same name. Step–by–step multivariate regression analysis was used to determine the factors affecting intrarenal hemodynamics.

Results. When analyzing the relationship of RI with clinical and laboratory parameters in all patients, it was revealed that the RI of the renal vessels are in direct correlation with the age of the patients and pulse pressure (PP) (Tab.1). The RI of the mouth of the RA and intrarenal arteries are inversely dependent on GFR (Tab.1), there was no statistically significant association with the severity of PU.

Table 1.

The relationship of the patient's age, PP and GFR with RI at the mouth of the RA and intrarenal arteries

Parameter	RI of the mouth of the RA	RI of the SA	RI of the IA
Age	r=0,322 (p=0,015)	r=0,477 (p=0,016)	r=0,485 (p=0,001)
PP	r=0,327 (p=0,025)	r=0,334 (p=0,016)	r=0,270 (p=0,034)
GFR according to the CKD–EPI formula	r= -0,364 (p=0,006)	r= -0,437 (p=0,001)	r= -0,392 (p=0,003)

In patients with polycystic fibrosis, the corticomedullary differentiation of the kidney structure is impaired, in order to correctly assess the relationship between IR and kidney size, patients with cystic kidney changes were excluded from the sample. It was found that the IR of the mouth of RA (r=0.369; p=0.006) and SA (r=0.376; p=0.007) is directly related to the length of the kidney, while IA is in reverse (r=–0.563; p=0.0001). The transverse size of the kidney was directly positively correlated with the RI of the mouth of RA (r=0.356; p=0.009), SA (r=0.520; p=0.0001) and IA (r=0.376; p=0.005).

To analyze structural changes, the thickness of the renal parenchyma and PPI were evaluated. In feedback with the renal parenchyma thickness index and the values of the PPI, there were RI RA (r=–0.439; p=0.004; r=–0.391; p=0.011), SA (r=–0.360; p=0.023; r=–0.332; p=0.037), IA (r=–0.309; p=0.033; r=–0.344; p=0.025). For a more detailed analysis of the relationship between clinical and laboratory parameters of IR, the sample, which is characterized by heterogeneity of diseases with fundamentally different pathogenesis, was divided into 2 groups: patients with glomerular diseases and patients with interstitial diseases (hypertension, pyelonephritis and TIN). This ratio was 48.05% and 36.83%.

In the group of patients with glomerular diseases, a positive correlation was found between RI and the severity of PU and a negative correlation with GFR (Tab.2). At the same time, in the group of glomerular diseases, the size of the kidney and indicators reflecting its structure, in particular the thickness of the parenchyma and PPI, did not depend on RI. Practically the opposite situation was observed in the group of patients with interstitial kidney lesions. Thus, the indices of vascular resistance did not correlate with the values of PU and GFR (determined by calculation formulas), but correlated with the size of the kidney (Tab.2).

Table 2.

The relationship of PU and RI of the mouth of the RA and parenchymal renal arteries in patients with glomerular diseases

Parameter	Glomerular diseases			Interstitial diseases		
	IR of the mouth of the RA	**IR of the SA**	**IR of the MA**	**IR of the mouth of the RA**	**IR of the SA**	**IR of the MA**
PU	r=0,464 (p=0,015)	r=0,471 (p=0,011)	r=0,405 (p=0,036)	r= -0,129 (p=0,548)	r= -0,256 (p=0,250)	r= -0,301 (p=0,153)
GFR according to the CKD–EPI formula	r= -0,498 (p=0,006)	r= -0,535 (p=0,002)	r= -0,495 (p=0,005)	r= -0,371 (p=0,052)	r= -0,218 (p=0,284)	r= -0,204 (p=0,297)
Kidney length	r=0,040 (p=0,842)	r= -0,026 (p=0,897)	r=0,070 (p=0,724)	r=0,356 (p=0,019)	r=0,567 (p=0,004)	r=0,793 (p=0,001)
Transverse size	r=0,039 (p=0,846)	r= -0,043 (p=0,829)	r=0,072 (p=0,716)	r=0,433 (p=0,027)	r=0,770 (p=0,001)	r=0,523 (p=0,006)
Parenchyma thickness	r= -0,254 (p=0,176)	r= -0,304 (p=0,096)	r=0,142 (p=0,455)	r= -0,397 (p=0,030)	r= -0,247 (p=0,041)	r= -0,218 (p=0,047)
PPI	r= -0,155 (p=0,412)	r= -0,229 (p=0,216)	r= -0,296 (p=0,112)	r= -0,490 (p=0,006)	r= -0,409 (p=0,031)	r= -0,393 (p=0,032)

The value of the RI of the RA mouth as a prognostic sign of deterioration of renal function had an area under the ROC curve of 0.667 (p=0.038), which characterizes its quality as good. The inflection point of the curve, i.e. the threshold value at which deterioration of renal function was observed, was 0.714, with sensitivity reaching 56% and specificity – 71%. Under the ROC curve, SA was greater for RI than for the mouth of RA 0.748 (p=0.002), with an inflection point of 0.66, in which sensitivity is 62.4% and specificity is 77%. The largest area under the ROC curve was determined for RI MA – 0.780 (p<0.001), where the inflection point of the curve was 0.654 with a sensitivity of 69% and specificity of 71% (fig.1).

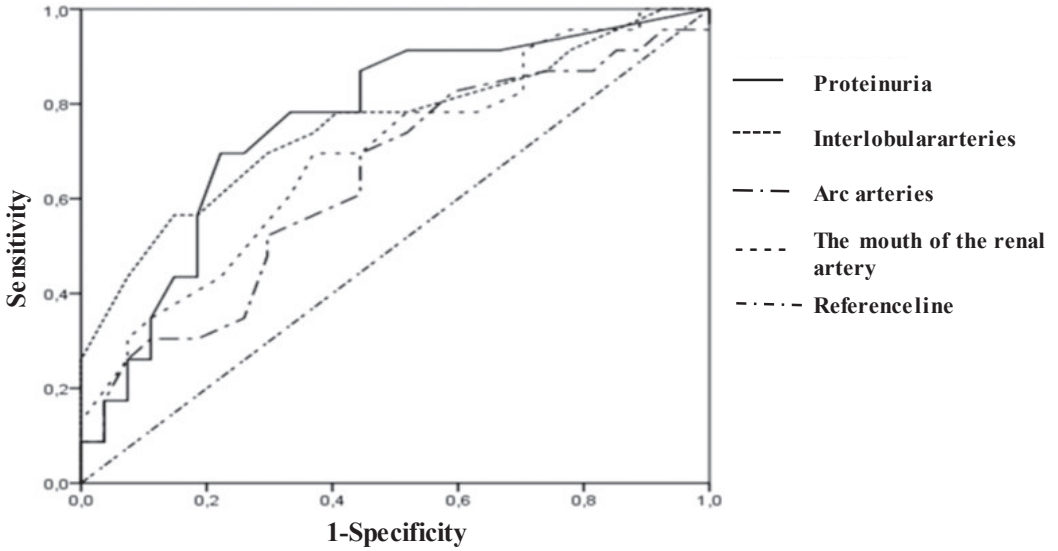

Figure 1. **ROC–curves for PU and RI of the mouth of the RA and intrarenal arteries in patients of the studied sample**

Thus, this study demonstrates that RI IA has the greatest prognostic significance for assessing the rate of progression of CKD. In addition, we compared the sensitivity and specificity of RI RA and intrarenal vessels with a reliable prognostic sign of deterioration of renal function – PU. The figure shows that the predictive value of RI is comparable to PU (AUC=0.748; p=0.002).

To assess the influence of factors determining intrarenal hemodynamics, a step–by–step multifactorial regression analysis was applied, which included the patient's age, BMI, PP, proteinuria value, GFR (calculated by CKD–EPI and determined by the Rehberg–Tareev formula), creatinine and uric acid concentrations in the blood. It turned out that among the studied parameters, the age of the patient (β=0.521; p=0.0001) and the concentration of creatinine in blood plasma (β=0.481; p=0.001; r2=0.49; p<0.001) significantly affect RI.

Discussion.

The results of the work carried out allow us to consider the measurement of RI in patients with CKD appropriate for a number of reasons. Thus, the value of RI directly depends on the patient's age and PP [2,5,10,16]. This result indicates that RI is a reflection of the degree of damage to the renal vessels, largely dependent on pathological processes such as hypertension and atherosclerosis. The direct relationship between the values of the RI of the mouth of the RA and PP indicates that this index reflects violations of systemic hemodynamics; this is also shown in other works [9]. It is important to note that an increase in IR IA serves as a risk factor for the development of cardiovascular diseases in elderly patients, and is also associated with a high risk on the Framingham scale [5,10,18]. In our work, it was shown that USDG with the calculation of the IR of kidney vessels of different calibers allows us to determine the signs and severity of impaired renal function and structure: a decrease in GFR, renal parenchyma thickness and changes in PPI.

In glomerular diseases, renal vascular IR is associated with the severity of PU and a decrease in GFR, probably due to fibrosis of the

renal parenchyma, while in interstitial diseases – violations of the size of the kidney and its structure. Whether the RI of the renal vessels reflects the severity of glomerulosclerosis is a controversial issue. Thus, in the works of J. Platt et al. [8,12], the absence of correlations between the values of RI and the severity of histological changes was shown. The same conclusions were reached by N. Bige et al. [8,13], and according to their results, isolated glomerular damage was not associated even with a change in RI. At the same time, in one of the recent studies on a fairly large sample (n=202) of patients with glomerulonephritis and interstitial tissue damage, it was shown that renal vascular RI correlates with the severity of glomerular sclerosis [8,22]. Previously also shown the relationship between glomerular sclerosis, interstitial tissue and the growth of RI [2]. However, given the generally contradictory results of the work, the absence of large randomized trials, it is difficult to say whether the change in the magnitude of IR reflects the degree of damage to the glomerular apparatus. It is likely that an increase in the RI of renal vessels of a smaller caliber reflects a lesion of the glomerular apparatus. In addition, both of these studies are characterized by the fact that there are patients with different groups of nephropathies in the sample. In our work, the data of patients with predominantly primary glomerular and predominantly interstitial nephropathy mechanisms were compared. Due to this, the correlation between RI and PU was noted for the first time.

The increased IR values obtained in the study of patients with predominantly interstitial kidney damage coincide with the data of other authors [14,19]. The main mechanisms that lead to such a connection are an increase in vascular resistance and intravascular pressure due to atherosclerosis of the branches of the renal arteries and fibrosis of the renal parenchyma.

In addition to the connection with clinical and laboratory parameters and the severity of histological changes, the importance of measuring the value of RI is dictated by the fact that its elevated and high values are associated with impaired renal function. One of the first studies showing the prognostic significance of IR in relation to the severity of nephropathy is a study by J. Platt et al. [15] conducted on a sample of patients with lupus nephritis. Much later, T. Sugiura et al. [21] showed the prognostic significance of IR in a sample of 311 people with CKD with a follow–up period of 2 years. Similar data were obtained in the work of N. Bige et al. [8]. At the same time, both studies showed a different threshold value of RI, which is associated with the study of vessels of different calibers, as well as the degree of decrease in GFR – at IR 0.70, the degree of decrease over 2 years was 10 ml/min 1.73 m2/year, and at IR 0.65 – 5 ml/min 1.73 m2/year. Given this difference, we examined vessels of different calibers. According to our data, RI IA is the most accurate parameter for determining the degree of progression of CKD, while prognostically unfavorable is The RI is more than 0.65. The prognostic value of this value coincides with that of a proven risk factor for CKD progression. It is important to emphasize that the IR of 0.65 is within the reference values, nevertheless it is associated with deterioration of renal function, which necessitates adequate therapy.

Conclusion. Thus, the most significant factors affecting the RI are the patient's age and serum creatinine concentration. The data of renal vascular ultrasound, in particular RI, make it possible to clarify the degree of renal fibrosis and can be used as an additional prognostic factor that allows predicting the rate of progression of CKD.

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