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RENAL RESISTIVE INDEX AND ARTERIAL STIFFNESS IN KIDNEY TRANSPLANTED PATIENTS

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Abstract

Measurement of renal resistive index is a non-invasive method used for assessment of microvascular lesions influenced by hemodynamic factors.

The aim of our study was to introduce modern methods for assessing the arterial rigidity in patients with renal transplantation, which enable to treat and reduce it (arterial rigidity is potentially reversible), and thus reduce the risk of cardiovascular morbidity and mortality in this population.

In a cross sectional study we assessed 28 kidney transplanted patients for pulse wave velocity, renal resistive index, ambulatory arterial stiffness index and pulse pressure. The data were statistically processed in a Statistica 7.1 for Windows.

The average age of the participants was 44.07 years, 64.29% were men, average BW was 74.28 kg and BMI 25.29 kg/m^2. The average graft duration was 82.28 months, and the average duration of hypertension was 142.89 months. Controlled hypertension was present in 35.71% of all hypertensive patients. Average pulse wave velocity was 6.64 ± 1.18 m/sec., ambulatory arterial stiffness index varied in the interval 0.36 ± 0.15 and the average renal resistive index of the graft's main renal artery was 0.66 ± 0.08. Multiple regression analysis in the group of patients with graft duration below 7 years showed that both renal resistive index of the graft's main renal artery and pulse wave velocity as dependent variables had significant and strong correlations with body weight and pulse pressure. Also, multiple regression analysis showed significant correlations between renal resistive index of graft's main renal artery and pulse wave velocity as dependent or independent variables respectively.

Our study showed that in the group of patients with graft duration less than a 7 years renal resistive index of the graft's main renal artery and pulse wave velocity were significantly related but this was not confirmed in the group of patients with graft duration over 7 years. Thus suggests that we are not aware of all the factors that influence this relationship and more research studies are needed in that direction involving a larger number of respondents i.e. large prospective multicenter cohort studies with sufficient long follow-up period.

***Key words*:** Renal resistive index, pulse wave velocity, kidney transplantation

Introduction

Arterial rigidity is an important biomarker for the assessment of cardiovascular disease and for the evaluation of cardiovascular risk. Also it is an independent predictor of cardiovascular morbidity and mortality in population with diabetes mellitus, hypertension and chronic kidney disease [1-3]. If arterial stiffness is assessed along with intima-media thickening (IMT) of the Carotid artery and the ankle-brachial index (ABI), macrovascular lesions will be precisely defined [4].

Also, for the cardiovascular morbidity and mortality, evaluation of the microvascular lesions is important (especially renal bed lesions).

Further, elucidating microvascular lesions, such as atherosclerotic kidney damage, non-invasive measurements of renal resistive index (RRI) can be helpful. According to some, RRI is a marker of microvascular status of the kidneys, but at the same time, according to other studies, it is also associated with arterial rigidity, i.e. it depends on central hemodynamic factors [5].

In population of hypertensive subjects resistant to antihypertensive medications, RRI is correlated with microalbuminuria, and can show the degree of kidney lesion as a target organ [6].

Despite of all the findings above, there are still no definitive conclusions about the role of RRI as a prognostic tool for renal impairment [7].
The golden standard for arterial rigidity assessment is pulse wave velocity (PWV) [8].
In patients with chronic kidney disease, RRI can be used for assessment of the renal impairment and further for monitoring its progress in the long term together with glomerular filtration rate (GFR) and proteinuria [9]. Studies that include renal transplant patients showed that the RRI mainly reflects characteristics of the recipient but not those of the graft.
A good assessment of the lesions of the micro and macrovascular circulation (including PWV and RRI) in hypertensive patients can provide a plan for appropriate therapy and prevention of cardiovascular disease [10].
The aim of our study was to introduce modern methods for assessing the arterial rigidity in patients with renal transplantation, which enable to treat and reduce it (arterial rigidity is potentially reversible), and thus reduce the risk of cardiovascular morbidity and mortality in this population. We also wanted to correlate the PWV and RRI with time from transplantation.

Materials and methods

Patients: In a cross sectional study we included 28 kidney transplanted patients, referred for a regular control in our department. The graft was assessed with doppler sonography (as a regular annual control), and RRI measurement. Ambulatory monitoring of the blood pressure was performed for 24 hours period. The values for the renal resistive index of the graft's main renal artery and the interlobar arteries, pulse wave velocity, and ambulatory arterial stiffness index were determined. Additionally patients were divided into two groups according to time from the transplantation (under and over 7 years with transplanted kidney). Current and formal smoking status was noted.

Renal resistive index measurement: Doppler sonography was performed at our department. We used convex array probe (Esaote MyLab Gamma Probe, Italy). The main renal artery and intrarenal arteries were visualized in duplex color mode, the RRI was calculated through the analysis of spectral Doppler (maximum systolic velocity – end diastolic velocity / maximum systolic velocity) obtained from 3 doppler curves at each different location in the kidney. RRI of the graft's main renal artery values were calculated as the average.

Measurement of arterial stiffness: The carotid-femoral pulse wave velocity (c-f PWV) was performed using Doppler sonography [11]. We preformed 24 hours ambulatory blood pressure (BP) monitoring (ABPM) by using automatic readers. Measurements were obtained every 20 minutes during the day and every 60 minutes during the night, making adjustments for each patient. Ambulatory arterial stiffness index (AASI) was derived from the data of 24 hours ambulatory blood pressure monitoring (ABPM). We calculated the AASI as 1 minus the regression slope of diastolic blood pressure (DBP) over the systolic BP (SBP) [12-13]. Pulse pressure (PP) was derived from ambulatory blood pressure monitoring (ABPM).

Equipment: 3 automatic readers of ASPEL S.A. (2007), 1 Esaote MyLab Ultrasonic Apparatus, manufactured by ESAOTE S.p.A, Genova, Italy with a linear probe (Esaote MyLab Gamma Probe) for measuring PWV, ECG (accessory part of the UC apparatus) and convex array probe for RRI measures.

Statistical analysis of the data is performed in a statistical program Statistica 7.1 for Windows. Descriptive statistics were done in series with numerical marks (PP average (PPa), PWV, AASI, RRI of main renal artery (RRIa). Data distribution was tested with Kolmogorov-Smirnov test; Lilliefors test; Shapiro - Wilks test (p). Differences of the analyzed parameters between the groups were tested by using Post-hoc LSD Test / (F; p) and Kruskal-Wallis ANOVA by Ranks / Multiple Comparisons p values (2-tailed) / (H; p), depending on the data distribution.
The correlation between dependent variable RRI of main renal artery and the analyzed parameters were analyzed using Pearson (r) and Spearman Rank Order (R) test, depending on data distribution.
The impact of the analyzed parameters (age, body weight, duration of hypertension (HTA), PP average, PWV/ RRI of the graft's main renal artery, AASI, smoking status) on the dependent variables PWV / RRI

of the main renal artery; were analyzed with multipe regression analysis. The level of significance was defined as $p<0.05$.

Results

The demographic and clinical characteristics of the examined patients are as follows: All 28 subjects had an average age of 44.07 years, men were 64.29%, average body weight was 74.28 kg and body mass index (BMI) 25.29. The average graft duration was 82.28 months, and the average duration of hypertension was 142.89 months, of which 35.71% were with satisfactory control under antihypertensive therapy. Regarding dipping status: the retained dipping status have 21.43%, non-dipper were 28.57% and reverse dipper were 50% of the examined patients. Descriptive statistics for PP average (PPa), PWV, AASI and RRI of the graft's main renal artery (RRIa) in all 28 patients is as follows: PPa varied in the interval 52.21 ± 8.96 mmHg, ± 95.00% CI: 48.74-55.69; the minimum value was 35.00 mmHg and the maximum value was 74.00 mmHg. PWV varied in the interval 6.64 ± 1.18 m / sec., ± 95.00% CI: 6.18-7.10; the minimum value is 4.67 m/sec and the maximum value was 8.90 m/sec. AASI varied in the interval 0.36 ± 0.15; ± 95.00% CI: 0.30-0.42; the minimum value was 0.00; and the maximum value is 0.62. RRIa varied in the interval 0.66 ± 0.08; ± 95.00% CI: 0.63-0.69; the minimum value was 0.49; and the maximum value is 0.80.

In the group of thirteen patients with a graft above 7 years of duration the demographic and clinical characteristics are as follows: average age of 47 years, men were 69.23%, average body weight 75.96 kg and BMI 25.79. The average graft duration was 135.85 months and the average duration of hypertension was 199.85 months, of which 38.46% with satisfactory control under antihypertensive therapy. Regarding dipping status: with retained dipping status were 7.69%, non-dipper were 30.77% and reverse dipper were 61.54%. Figure 1 shows descriptive statistics of PPa, PWV, AASI and RRIa in this group: PPa varied in the range 52.38 ± 9.15 mmHg, ± 95.00% CI: 46.85-57.92; the minimum value is 39.00 mmHg; and the maximum value was 74.00 mmHg. PWV varied in the interval 7.28 ± 0.88 m/sec., ± 95.00% CI: 6.75-7.82; the minimum value was 5.90 m/sec and the maximum value was 8.90 m/sec. AASI varies in the interval 0.41 ± 0.11; ± 95.00% CI: 0.34-0.47; the minimum value was 0.22; and the maximum value was 0.62. RRIa varied in the interval 0.68 ± 0.06; ± 95.00% CI: 0.64-0.72; the minimum value was 0.54; and the maximum value 0.80.

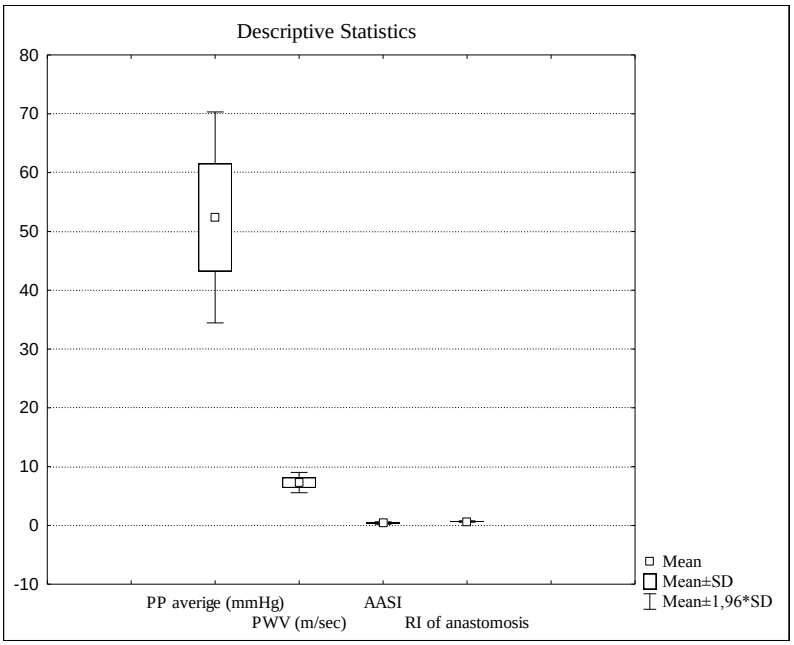

Figure 1. Descriptive Statistics for Pulse Preassure averige (PPa), Pulse Wave Velocity (PWV), AASI и RRI of main renal artery (RRIa), in the group with graft duration above 7 years

In the group with graft duration less than 7 years there were 15 examinees, with average age of 41.53 years, men were 60%. The average body weight in this group was 72.83 kg and BMI was 24.86. The average graft duration was 35.86 months and duration of hypertension averaged 93.53 months, of which 33.33% with satisfactory control under antihypertensive therapy and 66.67% with unsatisfactory control. In terms of dipping status: 33.33% patients had preserved status, 26.67% were non-dipper, and 40% were reverse dipper. PP average varied in the range 52.07 ± 9.11 mmHg, ± 95.00% CI: 47.02-57.11; the minimum value was 35.00 mmHg and the maximum value was 71.00 mmHg. PWV varied in the interval 6.08 ± 1.13 m / sec, ± 95.00% CI: 5.45-6.72; the minimum value was 4.67 m/sec and the maximum value was 8.50 m/sec. AASI varied in the interval 0.32 ± 0.18; ± 95.00% CI: 0.22-0.43; the minimum value was 0.00; and the maximum value was 0.53. RRIa varied in the interval 0.64 ± 0.09; ± 95.00% CI: 0.59-0.68; the minimum value was 0.49; and the maximum value was 0.80.

Comparative analysis between groups: there was no significant difference in PPa values among the groups (p = 0.99).

The results of the Post-hoc analysis concerning the inter-group differences of PWV (m/sec) are presented in Table 1. The mean value (M=7.28 m/sec) of PWV in patients with graft duration over 7 years {2} for p <0.01 (p=0.006) was significantly higher than the mean PWV value (M = 6.08 m/sec) in patients with graft duration below 7 years {3}.

Group	group with graft duration below 7 years {3} M=6,08
group with graft duration over 7 years {2} M=7.28	**0,006**

Table 1. Pulse Wave Velocity (m/sec) / Post-hoc LSD Test

No significant difference in AASI or RRIa values were found among the groups (p = 0.69; p = 0.33 respectively).

RRIa and PWV correlations with age, body weight, duration of hypertension, PPa, AASI, smoking status were separately done in subjects with graft duration over 7 years and in the group under 7 years.

The correlation *between RRIa and patients age* in over 7 years graft duration group is shown in Figure 2.

Strong positive significant correlation was found for r=0.63 and p <0.05. Namely, by increasing the age of patients for a single value (1 year) the RRIa value significantly (p <0.05) increased by 0.006 units.

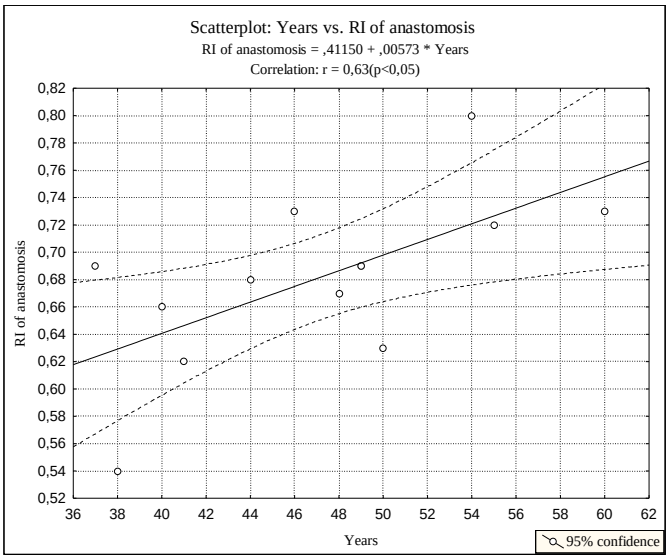

Figure 2. Correlation between RRI of main renal artery and patient age

Figure 3 shows the correlation *between RRIa and PPa* of the same patients which was strong and significant (r = 0.60 and p <0.05). Thus, for a PPa single value increasing (1 mmHg), the RRIa value significantly (p <0.05) increased by 0.004 units.

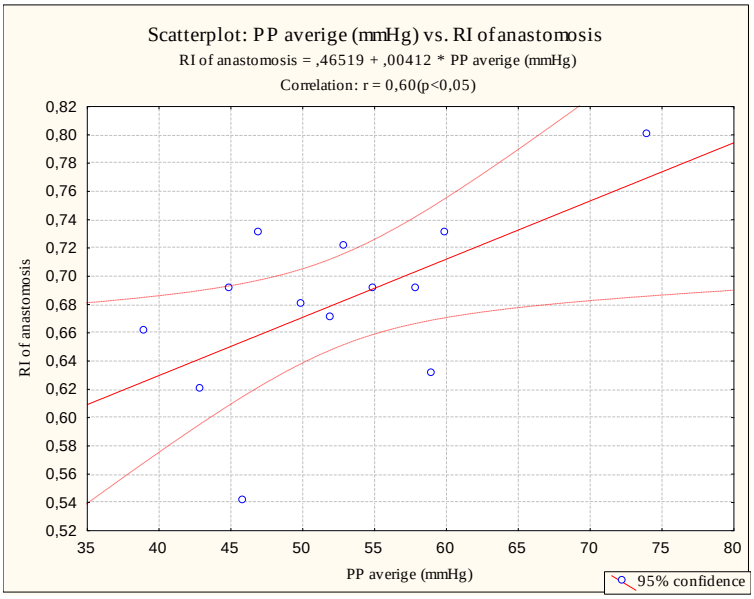

Figure 3. Correlation between RRI of main renal artery and average Pulse Pressure

Insignificant correlations were found for RRIa regarding body weight, duration of hypertension, PWV, smoking status and AASI.

A very strong but insignificant correlation was found in Multiple Regression analysis between RRIa as dependent variable and age, weight, duration of hypertension, PPa, PWV, AASI, smoking status

as independent variables; for R = 0.82 and F (8.4) = 1.00 and p <0.54. "Non-smoker" was taken as a reference category for patients smoking status.

Namely, the highest impact on RRIa had smoking status / Beta (-0.46 / p> 0.05 (p=0.30), then body weight (kg) / Beta (-0.46 / p> 0.05 (p=0.27)), PP average (mmHg) / Beta (0.44 / p> 0.05 (p=0.41), PWV (m/sec) / Beta (0.39 / p> 0.05 (p=0.42)), duration of HTA / Beta (0.21 / p> 0.05 (p=0.56)), age / Beta (0.17 / p> 0.05 (p=0.79), former smoker / Beta (0.06 / p> 0.05 (p=0.89)), and the lowest impact had AASI / Beta (-0.02 / p> 0.05 (p =0.96).

In the group of subjects with graft duration over 7 years insignificant correlations were found between PWV and age, body weight, duration of hypertension, PPa, AASI, RRIa and smoking status of patients individually.

The insignificant correlation for multiple regression analysis between PWV as dependent variable and age, body weight, duration of hypertension, smoking status, PPa, AASI, RRIa as independent variables was established. There was a high correlation for R = 0.79 and F (8.4) = 0.84 and p <0.61. "Non-smoker" was taken as a reference category for smoking status.

The highest impact on PWV had smoking status / Beta (0.49 / p> 0.05 (p = 0.29), followed by RIa / Beta (0.44 / p> 0.05 (p = 0.42), age / Beta (0.41 / p> 0.05 (p = 0.54), former smoker / Beta (0.40 / p> 0.05 (p = 0.34), PP average / Beta (-0.30 / p> 0.05 (p = 0.61), body weight / Beta (0.28 / p> 0.05 (p = 0.55), duration of HTA / Beta (-0.09 / p> 0.05 (p = 0.81)), and the weakest is the influence of AASI / Beta (-0.04 / p> 0.05 (p = 0.92).

The multivariate analysis revealed no significant predictor for RRIa and for PWV in the group with graft duration over 7 years.

In the group with graft duration below 7 years, RRIa was predicted by the recipient's body weight, average pulse pressure and pulse wave velocity (Table 2). Considering PWV (Table 3), body weight, average pulse pressure and RRIa were most powerful predictors.

In this group *correlations* were made for *RRIa* in relation to age, body weight, duration of hypertension, PPa, PWV, AASI and smoking status of the subjects and were found not to be significant.

Table 2 shows *multiple regression* between *RRIa as a dependent variable* and age, weight, duration of hypertension, PPa, PWV, AASI and smoking status as independent variables. Very strong correlation was found for R = 0.90 / F (8.6) = 3.22 and p <0.09. As a reference category for smoking status in patients was taken "Non-smoker".

The strongest influence on RIa had PP average / Beta (1.45 / p <0.01 (p = 0.006), then body weight / Beta (-0.93 / p <0.05 **(p = 0.02)**, PWV / Beta (0.77 / p <0.05 (**p = 0.03**), former smoker / Beta (-0.34 / p> 0.05 (p = 0.18), duration of HTA / Beta (-0.29 / p> 0.05 (p = 0.22), AASI / Beta (0.20 / p> 0.05 (p = 0.36), smoker status / Beta (0.19 / p> 0.05 (p = 0.48)), and the lowest impact had age / Beta (-0.19 / p> 0.05 (p = 0.51)).

The average increases of RRIa is by 0.01 units with each single value increment of PP average (1mmHg), (B = 0.01) / (p <0.01 (**p = 0.006**), while remaining parameters have unchanged values. With each increase in unit value (1 kg) of body weight, RRIa decreased on average by 0.005 (B = -0.005) / (p <0.05 (**p=0.02**) units, with the values of the remaining parameters unchanged.

With each unit increment (1 m/sec.) of PWV, RRIa increased on average by 0.06 (B = 0.06) / (p <0.05 (**p = 0.03**) units, with the values of the remaining parameters unchanged.

Regression summary for dependent variable: RRI of graft's main renal artery; R= 0,90; F(8,6)=3,22 и p<0,09						
N=15	Beta	Std.Err. of Beta	B	Std.Err. B	t(6)	p-level
Intercept			0,009	0,18	0,05	0,96
Years	-0,19	0,27	-0,002	0,003	-0,10	0,51
Body weight (kg)	-0,93	0,30	-0,005	0,002	-3,13	**0,02**
Duration of HTA	-0,29	0,21	-0,0005	0,0003	-1,37	0,22
Smoker	0,19	0,25	0,05	0,06	0,76	0,48
Former smoker	-0,34	0,22	-0,06	0,04	-1,50	0,18
PP average (mmHg)	1,45	0,35	0,01	0,003	4,16	**0,006**
PWV (m/sec)	0,77	0,28	0,06	0,02	2,76	**0,03**
AASI	0,20	0,20	0,10	0,10	0,99	0,36

Table 2. Multiple regression; Dependent variable: RRIa;
Independent variables: age, body weight, duration of HTA, PPa, PWV, AASI, smoking status

In this group *correlations* were made for *PWV* in relation to age, body weight, duration of hypertension, PPa, RRIa, AASI and smoking status of the subjects and were found not to be significant.
Table 3 shows *multiple regression* analysis between *PWV as dependent variable* and age, weight, duration of hypertension, PPa, RRIa, AASI and smoking status as independent variables. For R = 0.91 and F (8.6) = 3.49 and p <0.07 a very strong correlation was found. As a reference category for Smoking status in patients, "Non-smoker" was taken.

The strongest influence on PWV had PPa / Beta (-1.39 / p <0.01 (**p = 0.007**), then body weight / Beta (0.88 / p <0.05 (**p = 0.03**), RRIa / Beta (0.72 / p <0.05) (**p = 0.03**), smoking status / Beta (-0.32 / p> 0.05 (p = 0.20), age / Beta (0.31 / p> 0.05 (p = 0.24), duration of hypertension / Beta (0.26 / p> 0.05 (p = 0.26), former smoker / Beta (0.22 / p> 0.05 (p = 0.39), and weakest influence had AASI / Beta (-0.12 / p> 0.05 (p = 0.60).

With each unit increment (1 mmHg) of PP average, PWV decreased on average by 0.18 m/sec (B = -0.18) / (p <0.01 (**p = 0.007**) units, at unchanged values of other parameters.
With each increase in unit value (1 kg) of Body weight, PWV increased on average by 0.06m/sec (B = 0.06) / (p <0.05 (**p = 0.03**), at unchanged values of other parameters.
With each increment for a single value of RRIa, PWV increased on average by 9.54 m/sec (B = 9.54) / (p <0.05 (**p = 0.03**), with no change in other parameters.

Regression summary for dependent variable: PWV;
R= 0,91; F(8,6)=3,49 и p<0,07

N=15	Beta	Std.Err. of Beta	B	Std.Err. B	t(4)	p-level
Intercept			2,79	1,93	1,45	0,20
Years	0,31	0,24	0,04	0,03	1,31	0,24
Body weight (kg)	0,88	0,30	0,06	0,02	2,94	**0,03**
Duration of HTA	0,26	0,21	0,01	0,004	1,24	0,26
Smoker	-0,32	0,22	-1,03	0,71	-1,45	0,20
Former smoker	0,22	0,24	0,50	0,54	0,93	0,39
PP average (mmHg)	-1,39	0,35	-0,18	0,04	-4,02	**0,007**
AASI	-0,12	0,21	-0,73	1,30	-0,56	0,60
RRI of graft's main renal artery	0,72	0,26	9,54	3,45	2,76	**0,03**

Table 3. Multiple regression; Dependent variable: PWV;
Independent variables: age, body weight, duration of HTA, smoking status, PP average, AASI, RRIa

Discussion

In the Ohta Y et al.'s study, the authors performed measuring of RRI on main renal arteries and interlobar arteries and they were significantly correlated with PWV [14]. With the exception of above mentioned study that used the RRI of main renal artery of native kidneys, no other studies that were available to us used the resistive index of graft's main renal artery and compared it with arterial rigidity expressed and measured by PWV and AASI. As far as we know there are no reference values for RRI and RRIa, neither for native kidneys nor for a graft.

According to a study by Belen Ponte et al, RRI's reference and pathological values should be determined by age (97^{th} percentile). In B.Ponte's study, mean RRI was 0.64 $\pm$ 0.05 for women and 0.62 $\pm$ 0.05 for men [15].

According to Perpaolo Di Nicolo and Antonio Granata, any condition that affects pulse pressure, left ventricular out flow, vascular distensibility of large arteries and aorta will have an impact on peak systolic velocity (PSV), and thus on the RRI; but also any condition that will affect on heart rate, renal

capillary wedge pressure and peripheral resistance will affect end diastolic velocity (EDV) and thereby again the RRI [16].

Not all factors affecting the RRI value are known and they may have systemic hemodynamic and / or local origin (in our case renal origin)[17].

According to all above mentioned, RRI of the graft in kidney transplanted patients changes because of the recipients hemodynamic features and don't reflect characteristics of the graft [18].

All of this has inspired us to investigate the relationship between RRIa and arterial rigidity in kidney transplanted patients.

The mean value of PWV in the group with graft duration over 7 years was 7.28 m/sec., while in the group with graft duration less than 7 years was 6.08 m/sec. which was significantly different. This might be explained by several factors. It is known that initially, shortly after the kidney transplant, the recipient decreases arterial rigidity [19] Then over the time it increases again due to numerous factors [19] (longer duration of arterial hypertension, as well as the presence of other risk factors for atherosclerosis: proteinuria, a state of permanent stress, inflammation, further impairment of graft function, etc.). In our study the average hypertension duration was 199.8 months in the group with graft duration over 7 years and in the group with graft duration less than 7 years it was 93.5 months.

The RRIa's mean value in patients with longer graft duration was 0.68 and in the other group was 0.64 without significant difference between them.

The strong influence and association between RRI and aortic rigidity, and between RRI and atherosclerosis has already been well established in several papers as well as associations with pulse pressure , and with other parameters for arterial rigidity, other cardiovascular parameters and endothelial dysfunction [10,20-22]

PP in the young population is not considered the most ideal indicator of arterial rigidity, but in the older population (over 50-60 years) it is a powerful predictor of Cardiovascular Disease. [1] Our study confirmed already established fact of connection between RRI and PP (pulse pressure). [23] We found no correlation between PP and PWV. This we could explain with a generally younger average age of the respondents (47 years average in the group with graft duration over 7 years and the group with graft duration less than 7 years with average of 41.5 years).

Physiological process of aging, that includes progression of aortic rigidity, leads to increased arterial pulse pressure (PP) which eventually leads to increased renal vascular resistance (RRI)[24] This was shown in our study with the highly positive significant correlation of RRI and age in the graft duration over 7 years group, but not in the group with graft duration below 7 years. In the Heine GH study with transplanted kidney populations, there was a weak correlation between allograft RRI and recipient age, whereas a strong correlation was found between graft RRI and recipient's PP, intima media thickness (IMT) and ankle brachial index (ABI)[5].

One would also expect to have a significant correlation between PWV with age, which has already been established in a number of studies (primarily due to increased arterial rigidity associated with aging)[25-26]. In our study we did not have such a significant correlation that may be due to limited sample size and relatively young sample size.

There was no significant correlation between RRI and duration of hypertension, as well as PWV and hypertension duration, which can be explained by the fact that hypertension duration alone do not play such a significant role, but whether under antihypertensive therapy it is adequately regulated or not. Also there are a number of confounding factors to consider.

It is reported in the literature that RRI is associated with body weight, height, and female sex as anthropometric factors. Also, several studies reported that reduced body weight led to reducing PWV values[25-26]. In our study, the correlations between RRIa or PWV and body weight in both groups were statistically insignificant. But in the graft duration below 7 years group, multiple regression analysis showed that both RRIa and PWV as independent variables had significant and strong correlations with body weight and PP. Also, multiple regression analysis showed significant correlations between RRIa and PWV as dependent or independent variables respectively.

Our study has several limitations: firstly this study was a cross sectional and it had a small number of participants, secondly the ultrasound measurements might be operator-dependent and third limitation is that we didn't analysed the immunosuppressive therapy for which it is known that has atherogenic components.

Conclusion

In conclusion**,** RRI and PWV represent useful tools for cardiovascular risk assessment. Our study showed that in the group of patients with graft duration less than 7 years RRIa and PWV were significantly related, but this was not confirmed in the group of patients with graft duration over 7 years. This finding suggests that we are not aware of all the factors that influence this relationship and more research studies are needed in that direction involving a larger number of respondents i.e. large prospective multicenter cohort studies with sufficient long follow-up period.

List of abbreviations

AASI	Ambulatory arterial stiffness index
ABPM	Ambulatory blood pressure monitoring
ABI	Ankle-brachial index
BP	Blood pressure
BMI	Body Mass Index
c-f PWV	Carotid-femoral pulse wave velocity
DBP	Diastolic blood pressure
GFR	Glomerular filtration rate
HTA	Hypertension
IMT	Intima media thickness
PP	Pulse pressure
PPa	Pulse pressure average
PWV	Pulse Wave Velocity
RRI	Renal resistive index
RRIa	Renal resistive index of graft's main renal artery
SBP	Systolic blood pressure

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