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Scientific Poster

C-441 Daily monitoring patients with renal transplant: A way to better understand the relationship between Doppler indices and renal function

S. D. Bolboaca (Cluj-Napoca/RO)
M. D. Lucan (Cluj-Napoca/RO)
C. Botar-Jid (Cluj-Napoca/RO)
C. Reit (Cluj-Napoca/RO)
C. Lapusan (Cluj-Napoca/RO)
S. Dudea (Cluj-Napoca/RO)

Topic: Genitourinary / Kidney

Purpose

Transplantation has revolutionized the treatment of end stage renal disease by proving more cost effective than haemodialysis [1], with a lower morbidity and improved quality of life. [2]

An ultrasound examination of the transplanted kidney includes a gray scale ultrasound as well as Doppler examination. Color and power Doppler reveal important information. Measurements of the resistance index (RI), pulsatility index (PI) and systolic-diastolic ratio (SDR) to quantify changes in the spectral Doppler waveform can be of great help, particularly in the first weeks following transplantation. Doppler examination should evaluate the vessels to and from the transplant, as well as the parenchyma. Calculation of indices aims to detect the presence of increased vascular resistance. [3]

Routine ultrasound examination may assess the complications that occur after kidney transplantation: parenchymal complications (acute tubular necrosis, acute and accelerated acute rejection, and nephrotoxicity), vascular complications (renal vein thrombosis or occlusion, renal artery thrombosis, renal artery stenosis), and urological complications (urinary fistula and urinoma, ureteral obstruction and hydronephrosis).

The usefulness of ultrasonography in the assessment of renal transplantation complications is well established but, the data in the medical literature discussing the relation between ultrasound findings and renal allograft function are contradictory. [4]

To evaluate the correlation between Doppler indices and renal function in patients with different renal post-transplant evolution, Doppler parameters were compared with serum creatinine.

Methods and Materials

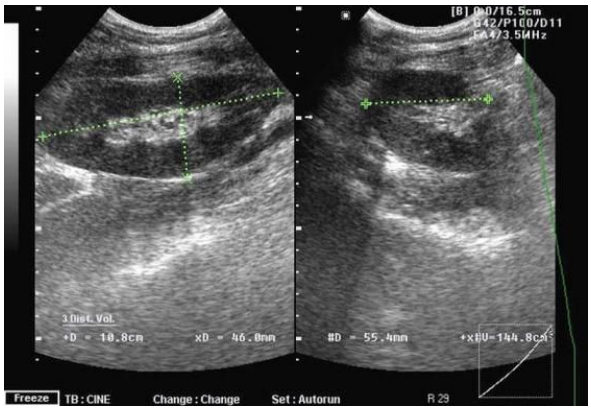
We studied a sample of 122 patients with renal transplants in the Clinical Institute of Urology and Kidney Transplant, Cluj-Napoca between October 2000 and December 2002. There were 37 female with mean age 35 years (range 10 - 63 years) and 85 male with mean age of 30 years old (range 2.4 69 years).
25 female and 62 male received the transplanted kidney from a living donor. The other patients received kidneys from cadaver donors.
High-resolution 3.5 to 5 MHz convex transducer with color and pulsed Doppler (Medison SONOACE 600C) was used. Doppler measurements and renal function were monitored daily for a period of 20 days post-transplant. The ultrasound exam was performed by the same radiologist.
The transplanted kidney was assessed by gray scale imaging in term of parenchymal echogenicity, definition of the cortical/medullary junction, collecting system, and estimation of the allograft volume. The allograft volume was estimated on transversal and longitudinal images (Figure 1[*1]) and the Medison SONOACE 600C software automatically computed the allograft volume using the corresponding formula[*2]. [5]
After assessing the allograft volume, the renal arterial perfusion and venous patency was evaluated using color (Figure 2[*3]) and power (Figure 3[*4]) Doppler imaging. The Doppler investigation was obtained in the first day after transplantation and then repeated at an interval of 24 hours, 20 post-transplant days. Using color Doppler on a longitudinal allograft slice we were able to visualize an interlobar artery of the middle third of the allograft, where the sample volume was placed. (Figure 4[*5]) The following parameters were assessed (Figure 5[*6]) using corresponding formulas [5]:

- Resistive index [*7](RI)
- Pulsatility index [*8](PI)
- Systolic-diastolic ratio [*9](SDR)

Based on clinical and biological evolution, and in 36 patients on the transplanted kidney biopsy, we grouped the renal transplant evolution into five categories: normal evolution, nephrotoxicity, tubular necrosis, rejection, and renal dysfunction. We used the following criteria:
The normal value for the pulsatility index: 1.25 [5]
- the pathologic value: > 1.25 (Figure 6[*10])
The normal value for the resistive index: 0.7 - 0.8 [6, 7]
- the pathologic value: > 0.9 (Figure 7[*11])
- the border value: 0.8 - 0.9
The normal value for the systolic-diastolic ratio: 3 [5]
- the pathological value: > 3 (Figure 8[*12])
The normal value for the transplanted allograft volume: 90-180 cm^3 (Figure 9[*13]) [5]
The normal serum creatinine level: 1.2 mg/dL
- the pathologic value: > 1.2 mg/dL

The Doppler indices and transplanted kidney volume were correlated with serum creatinine level using Pearson correlation coefficient, STATISTICA software, Basic Statistics module. The graphics were made using Microsoft Excel. The results are expressed as mean and 95% confidence interval, and a p value for Pearson correlation coefficient and Student Test. If the p value was less than 0.05, the results were considered statistically significant.

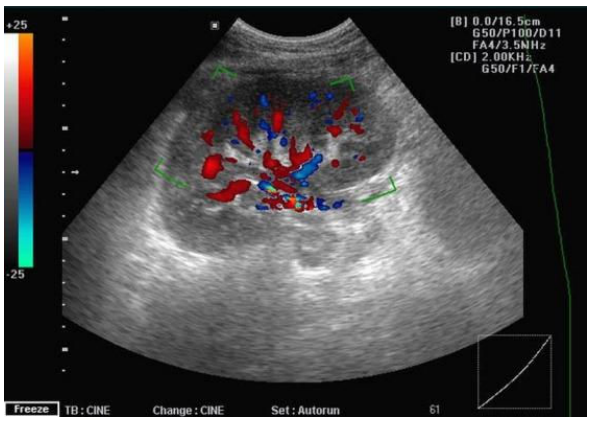
Linked images in Methods and Materials:



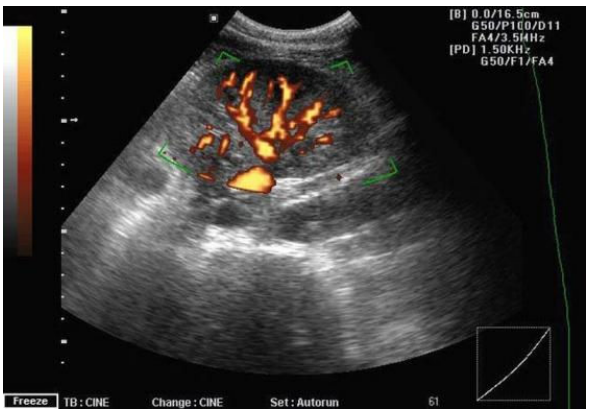
*1: Figure 1. A normal gray scale ultrasound image of the transplant kidney in longitudinal and transverse axes. Assessment of the allograft volume.

$$V = 0.48 \times longitudinal \times transverse \times AP\_diameters$$

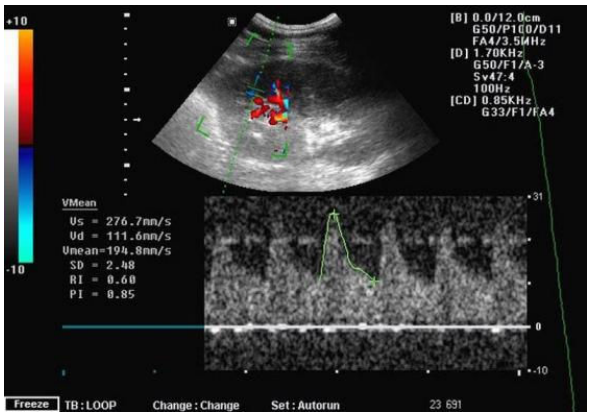
*2:



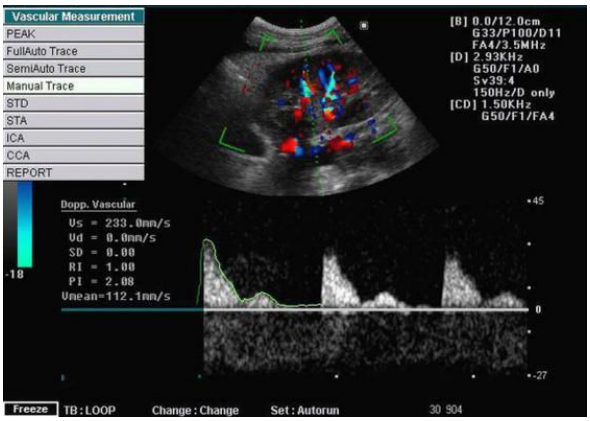
*3: Figure 2. Color Doppler imaging demonstration of normal flow within the transplant.



*4: Figure 3. Power Doppler imaging demonstration of normal flow within the transplant.



*5: Figure 4. Spectral-Doppler waveform of the allograft artery.



*6: Figure 5. Using color Doppler for index assessment.

$$RI = \frac{PeakSystolic\,Velocity - End\,Diastolic\,Velocity}{PeakSystolic\,Velocity}$$

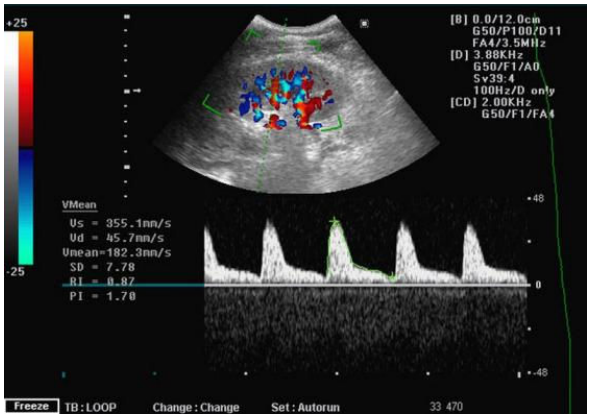
*7:

$$PI = \frac{PeakSystolic\,Velocity - End\,Diastolic\,Velocity}{Mean\,Velocity}$$

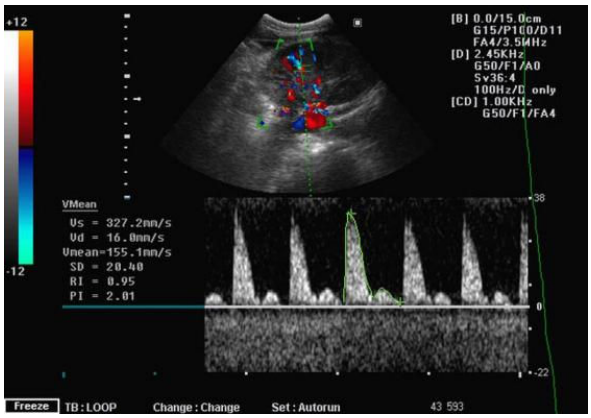
*8:

$$SDR = \frac{PeakSystolic\,Velocity}{Lowest\,Diastolic\,Velocity}$$

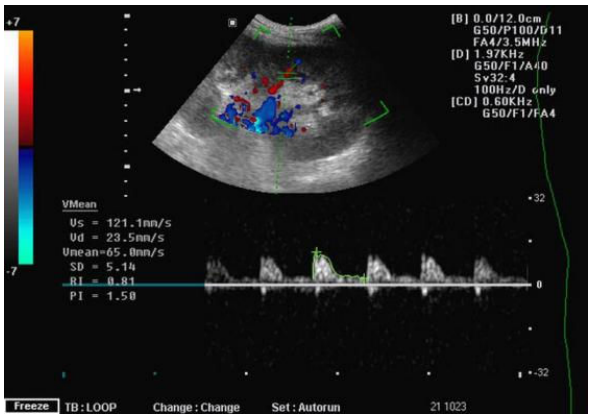
*9:



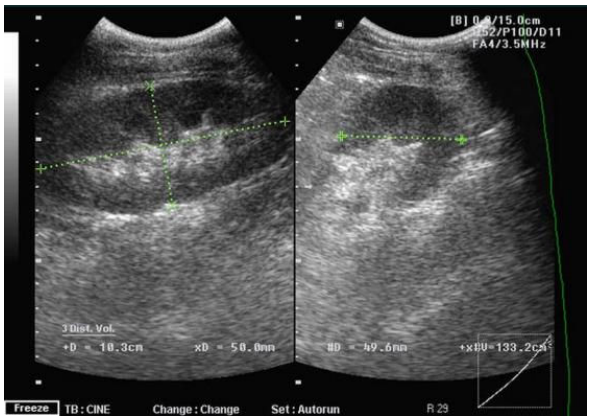
*10: Figure 6. Color Doppler ultrasound of the transplant renal artery showing a pathological PI.



*11: Figure 7. Color Doppler ultrasound of the transplant renal artery showing a pathological RI.



*12: Figure 8. Color Doppler ultrasound of the transplant renal artery showing a pathological SDR.



*13: Figure 9. B mode ultrasound image of a transplant kidney showing a normal allograft volume.

Results

The type of allograft transplant evolution in the studied sample was: normal evolution in 33, nephrotoxicity in 17, tubular necrosis in 12, allograft rejection in 29, and renal dysfunction in 31.
The means and 95% confidence intervals for Doppler indices (RI, PI, and SDR), allograft volume and serum creatinine were computed and are presented in the Table 1[*14] and Table 2[*15]. The evolutions of the parameters were presented in figure 10[*16], 11[*17], 12[*18], 13[*19], 14[*20].
In order to assess whether there are any significant differences between means of normal evolution parameters and means of the other post-transplant evolution type were performed Students t-test. There are significant differences between RI means for normal post-transplant evolution and the RI means from other post-transplant evolution type (nephrotoxicity p=0.012; tubular necrosis p=0.000; rejection p=0.000; and renal dysfunction p=0.011). The differences are also significant if the PI means for normal post-transplant evolution is compared with the PI means for other types of evolution (nephrotoxicity p=0.000; tubular necrosis p=0.000; rejection p=0.000; and renal dysfunction p=0.044). There were no significant differences between allograft volume means of the patients with normal post-transplant evolution and allograft volume means of the patient with nephrotoxicity (p=0.475) but the differences are significant if compares the normal evolution with all the evolution assessed (tubular necrosis p=0.020; rejection p=0.000; and renal dysfunction p=0.023). For the serum creatinine level we found that there are statistically significant differences between the normal evolution and all the other type of post-transplant evolution assessed ($p < 0.000$).
The correlation between Doppler indices and serum creatinine were statistically significant for the patients with normal allograft evolution, if the assessment was performed for 12 days as comparing with 20 days assessments (Table 3[*21] and Table 4[*22]). The stronger correlation was obtained between PI and serum creatinine level (Figure 15[*23]). For the patients with nephrotoxicity, there was a significant correlation between RI and creatinine serum level (p=0.040) at 12 days assessment, correlation which is also significant at 20 days assessment (p=0.016). At 20 days assessment there was also a statistically significant correlation between PI and serum creatinine level (p=0.022). In patients with tubular necrosis there was a significant correlation only between allograft volume and serum creatinine level, at 12 days assessment (p=0.022; Figure 16[*24]) as well as at 20 days assessment (0.000). The same results can be seen in the patients with renal dysfunction (p=0.032, 12 days assessment; and p=0.008, 20 days assessment; Figure 17[*25]).

Discussion

The physician faces a challenge in trying to use noninvasive diagnostic tools for post-transplantation renal assessment. Accurate diagnosis is important for allograft survival and none of the noninvasive methods is as accurate as biopsy. [8] Gray scale, color and power Doppler ultrasound examination are routinely performed in the

postoperative period.
The color Doppler ultrasound examination allows a global assessment of the intrarenal vasculature and identification of the transplant artery and vein. It is generally accepted that a single isolated Doppler examination is unhelpful and serial evaluation is required. [9]
The renal transplant complications often share similar or identical ultrasonographic and Doppler feature that can cause a diagnostic dilemma for the radiologist. [10] Elevation of the RI above 0.9 or progressive elevation above a normal baseline is good evidence of renal dysfunction [10] but is often nonspecific [11], and must be interpreted in the context of time of onset of dysfunction, clinical status and biochemical tests.
Table 5 *26 present the normal range of values for RI and PI reported by different authors for normal renal allografts evolution. For the normal post-transplant evolution, our results are comparable with the Krumme et al results. [12]
We found statistically significant correlation between serum creatinine and Doppler indices if the evaluation is performed for 12 days post-transplant. There was no correlation if the assessment was made for 20 post-transplant days. This can be explained by the linearity of the relation between Doppler indices and serum creatinine in the first 12 days post-transplant, evolution that was not seen after the 13th days post-transplant.
There are controversial reports in the medical literature about relations between Doppler indices and serum renal parameters. These controversial may be due to the variability in renal post-transplant evolution. [13] Some authors state that the intrarenal arterial Doppler findings dependent on various extrarenal factors such as recipient's age and hemodynamic situation. [14] Other authors affirm that neither grading of vascularity on power Doppler images, RI measurement, nor the combination of these methods are an accurate means of detecting renal allograft complications. [13]

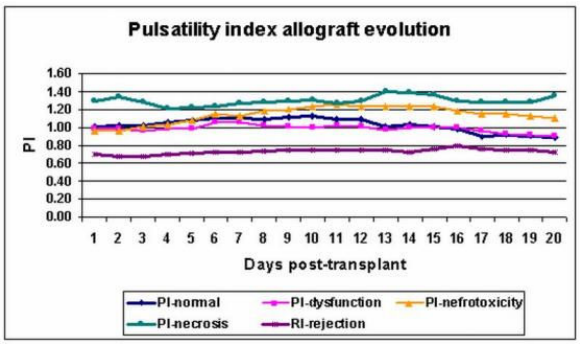
Linked images in Results:

	PI	RI	SDR	Graft volume	Serum creatinine
Normal evolution	1.028 [0.99-1.06]	0.66 [0.64-0.68]	3.05 [2.90-3.19]	207.6 [199.7-215.5]	1.11 [0.91-1.31]
Nephrotoxicity	1.141 [1.09-1.18]	0.69 [0.67-0.71]	5.41 [4.51-6.31]	204.3 [199.0-209.6]	1.99 [1.79-2.19]
Tubular necrosis	1.297 [1.27-1.32]	0.74 [0.74-0.75]	5.59 [4.71-6.47]	227.8 [212.5-243.1]	3.60 [2.98-4.22]
Graft reject	1.255 [1.22-1.29]	0.73 [0.72-0.75]	4.39 [4.11-4.67]	244.1 [232.0-256.1]	1.82 [1.50-2.14]
Renal dysfunction	0.988 [0.97-1.01]	0.63 [0.63-0.64]	2.80 [2.73-2.85]	223.4 [211.9-234.8]	1.77 [1.47-2.07]

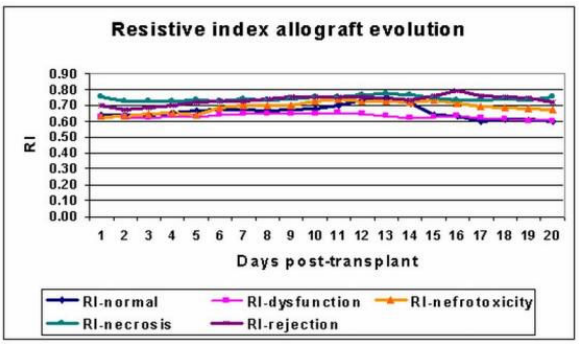
*14: Table 1. Means and 95% confidence intervals performed for the PI, RI, SDR, graft volume, and serum creatinine level differentiated by evolution type at 20 days assessment.

	PI	RI	SDR	Graft volume	Serum creatinine
Normal evolution	1.08 [1.05-1.10]	0.67 [0.65-0.69]	3.26 [3.16-3.35]	209.1 [199.4-218.8]	1.22 [0.91-1.53]
Nephrotoxicity	1.12 [1.05-1.19]	0.68 [0.66-0.71]	4.97 [3.45-6.49]	199.6 [192.9-206.3]	1.98 [1.64-2.31]
Tubular necrosis	1.28 [1.25-1.30]	0.74 [0.73-0.75]	4.72 [4.46-4.98]	207.4 [193.6-221.3]	3.83 [2.80-4.86]
Graft reject	1.23 [1.17-1.28]	0.72 [0.71-0.74]	4.21 [3.77-4.65]	230.5 [214.7-246.4]	1.88 [1.32-2.44]
Renal dysfunction	1.01 [0.99-1.03]	0.64 [0.63-0.65]	2.87 [2.83-2.91]	212.5 [195.9-229.1]	1.84 [1.30-2.37]

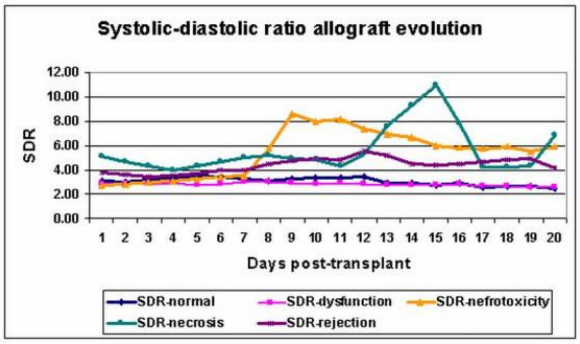
*15: Table 2. Means and 95% confidence intervals performed for the PI, RI, SDR, graft volume, and serum creatinine level differentiated by evolution type at 12 days assessment.



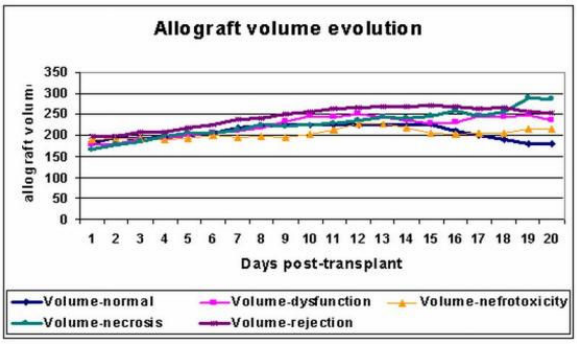
*16: Figure 10. Serial PI values of the kidney allograft - 20 days assessment.



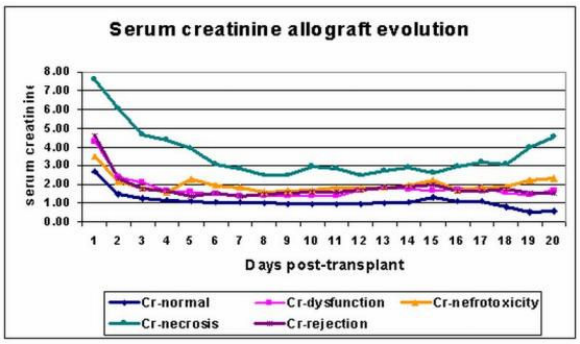
*17: Figure 11. Serial RI values of the kidney allograft - 20 days assessment.



*18: Figure 12. Serial SDR values of the kidney allograft - 20 days assessment.



*19: Figure 13. Allograft volume evolution 20 days assessment.



*20: Figure 14. Serum creatinine 20 days post/transplant evolution.

Evolutions	PI - creatinine	RI - creatinine	SDR - creatinine	Creatinine - volume
Normal	**0.003**	**0.050**	**0.049**	**0.007**
Nephrotoxicity	0.052	**0.040**	0.139	0.374
Tubular necrosis	0.564	0.629	0.691	**0.000**
Rejection	0.068	0.151	0.381	0.090
Renal dysfunction	0.127	0.057	0.130	**0.032**

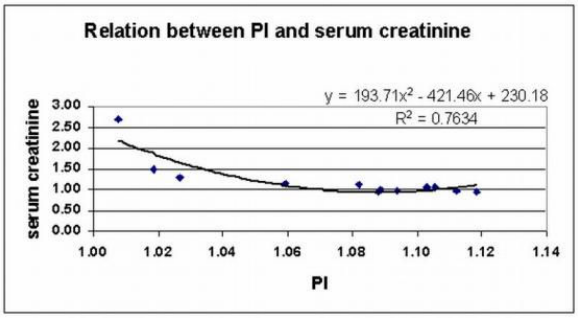
* Correlation is statistically significant if $p < 0.05$

21: Table 3. Correlations between Doppler indices and serum creatinine level 12 days assessment.

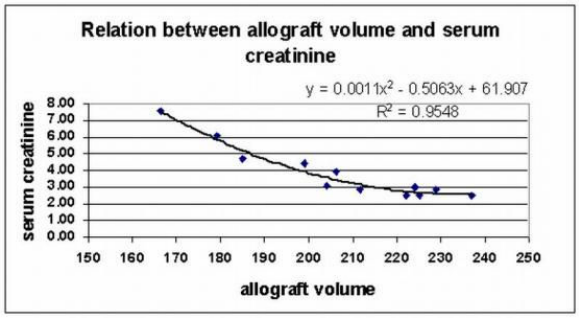
Evolutions	PI - creatinine	RI - creatinine	SDR - creatinine	Creatinine - volume
Normal	0.637	0.925	0.510	0.479
Nephrotoxicity	**0.022**	**0.016**	0.073	0.535
Tubular necrosis	0.771	0.341	0.285	**0.022**
Rejection	**0.029**	0.096	0.234	0.062
Renal dysfunction	0.582	0.433	0.755	**0.008**

* Correlations are significant if $p < 0.05$

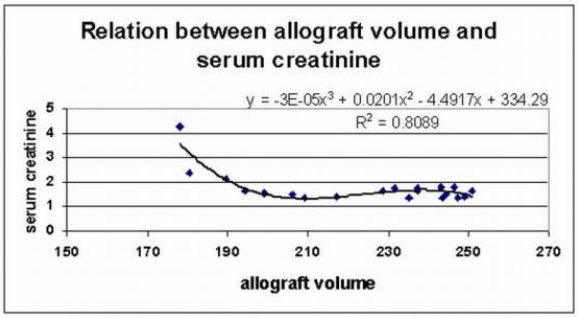
22: Table 4. Correlations between Doppler indices and serum creatinine level 20 days assessment.



*23: Figure 15. Normal post-transplant evolution: relationship between PI and serum creatinine. Correlation coefficient equal with 0.8737, that means a strong correlation between PI and serum creatinine.



*24: Figure 16. Tubular necrosis post-transplant evolution: relationship between allograft volume and serum creatinine. Correlation coefficient equal with 0.977, that means a strong correlation between allograft volume and serum creatinine.



*25: Figure 17. Renal dysfunction post-transplant evolution: relationship between allograft volume and serum creatinine. Correlation coefficient equal with 0.899, that means a strong correlation between allograft volume and serum creatinine.

Author	n	RI*	PI*	Graft Donor
Merkus et al [1]	123	[0.48-0.66]		cadaveric
Merkus et al [1]	20	[0.46-0.64]		living-related
Frauchiger et al [2]	14	[0.62-0.74]	[1.13-1.69]	not specified
Johnson et al [3]	27			not specified
Salgado et al [4]	37		[0.84-1.03]	cadaveric
Don et al [5]	34	[0.58-0.72]		cadaveric
Don et al [5]	32	[0.54-0.66]		living-related
Schwaighofer et al [6]	35	[0.59-0.75]		not specified
Krumme et al [7]	110	[0.63-0.77]	[1.15-1.57]	not specified

* means ± sd

*26: Table 5. Normal reference Doppler index values for kidney allograft measured at interlobar arteries reported by different authors.

Conclusion

Color Doppler is a non-invasive diagnostic method that provides flow-metric quantitative parameters for the assessment of the renal transplant.
Correlation between Doppler indices and serum creatinine was found to be different according to post-transplant evolution. This can explain the controversial opinions in the medical literature.
More over, the correlations have different significance if the assessment is made for 12 post-transplant days as compared with the 20 days post-transplant assessment.

References

[1] Blommers T, Schabacher B, Corry RJ. Transplant and Dialysis: The cost/benefit question. Iowa Med 1984: January:15-7.
[2] Landsberg DN, Shackleton CR, Keown PA, Cameron EC, Manson D. Renal Transplantation. BC Med J 1993: 35: 801-4.
[3] Jakobsen JÅ, Brabrand K, Egge TS, Hartmann A. Doppler Examination of the Allografted Kidney. Acta Radiologica 2003: 44 (1): 3.
[4] Tublin ME, Dodd III GD. Sonography of renal transplantation. Radiol Clin North Am 1995: 33: 447.
[5] Badea R, Dudea S, Mircea P, Stamatian F. Tratat de ultrasonografie clinică. Organele abdominale transplantate. Bucuresti, Romania, Editura Medicala Bucuresti: 2000 p: 503-20.
[6] Grant EG, Perrella RR. Wishing won't make it so: duplex Doppler sonography in the evaluation of renal transplant dysfunction. Ajr - American Journal of Roentgenology 1990: 155: 538-9.
[7] Don S, Kopecky KK, Filo RS, et al. Duplex Doppler US of renal allografts: causes of elevated resistive index. Radiology 1989: 171: 709-12.
[8] Isiklar I, Uzuner O, Demirag A, Haberal M. Early Postoperative Ulrtasound of Normally Functioning Transplanted Kidneys: Abnormal Findings and Their Significance. transplantation Proceedings 1999:31: 3320-3.
[9] Baxter GM. Ultrasound of Renal Transplantation. Clinical Radiology 2001: 56: 802-18.
[10] Grant EG. Ultrasound in Renal Transplantation. In: Benson CB, Doubilet PM., eds. Syllabus:State-of-the-Art Genitourinary Ultrasound course. Rockville MD: American Institute of Ultrasound in Medicine 1993: 29-31.
[11] Don S, Kopecky KK, Filo RS, et al. Duplex Doppler US of renal allografts: causes of elevated resistive index. Radiology 1989: 171: 709-12.
[12] Salgado O, Gracia R, Henriquez C, Rosales B, Sulbarán P. Severely Elevates Intrarenal Arterial Impedance and Abnormal Venous Flow Pattern in a Normal Functioning Kidney Graft. Transplantation Proceedings 2003: 35: 1772-4.
[13] Chow L, Sommer FG, Huang J, Li KC. Power Doppler imaging and resistance index measurement in the evaluation of acute renal transplant rejection. J Clin Ultrasound 2001: 29(9): 483-90.
[14] Restrepo Schafer IK, Schwerk WB, Muller TF, Prinz H, Gorg C, Arnold R, Intrarenal doppler flow analysis in patients with kidney transplantation and stable transplant function, Ultraschall Med. 1999: 20(3): 87-92.

The Authors

Sorana Daniela Bolboaca MD (Cluj-Napoca/Romania). Mihai Lucan[2] MD, PhD (Cluj-Napoca/Romania). Carolina Botar-Jid[3] MD (Cluj-Napoca/Romania). Cristina Reit[3] MD (Cluj-Napoca/Romania). Carmen Lapusan[2] MD (Cluj-Napoca/Romania). Sorin Dudea[3] MD, PhD (Cluj-Napoca/Romania).

[1] Iuliu Hatieganu University of Medicine and Pharmacy, Cluj-Napoca, Romania

[2] Clinical Institutes of Urology and Kidney Transplant, Cluj-Napoca, Romania

[3] Clinical County Hospital, Cluj-Napoca, Romania

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Creatinine

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