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) and the Medison SONOACE 600C software automatically computed the allograft volume using the corresponding formula [5].

After assessing the allograft volume, the renal arterial perfusion and venous patency was evaluated using color (Figure 2) and power (Figure 3) 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) The following parameters were assessed (Figure 5) using corresponding formulas [5]:

- **Resistive index** (RI)
- **Pulsatility index** (PI)
- **Systolic-diastolic ratio** (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)
- The normal value for the resistive index: 0.7 - 0.8 [6, 7]
- The pathologic value: > 0.9 (Figure 7)
- The border value: 0.8 - 0.9
- The normal value for the systolic-diastolic ratio: 3 [5]
- The pathalogical value: > 3 (Figure 8)

- The normal value for the transplanted allograft volume: 90-180 cm³ (Figure 9) [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.

*2:

\[ V = 0.48 \times \text{longitudinal} \times \text{transverse} \times \text{AP diameters} \]

*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.

$$RI = \frac{Peak\text{-}Systolic\text{-}Velocity - End\text{-}Diastolic\text{-}Velocity}{Peak\text{-}Systolic\text{-}Velocity}$$

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

$$PI = \frac{Peak\text{-}Systolic\text{-}Velocity - End\text{-}Diastolic\text{-}Velocity}{Mean\text{-}Velocity}$$

*7:

$$SDR = \frac{Peak\text{-}Systolic\text{-}Velocity}{Lowest\text{-}Diastolic\text{-}Velocity}$$

*8:

*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 \(^\text{14}\) and Table 2 \(^\text{15}\). The evolutions of the parameters were presented in figure 10 \(^\text{16}\), 11 \(^\text{17}\), 12 \(^\text{18}\), 13 \(^\text{19}\), 14 \(^\text{20}\).

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 \(^\text{21}\) and Table 4 \(^\text{22}\)). The stronger correlation was obtained between PI and serum creatinine level (Figure 15 \(^\text{23}\)). 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 \(^\text{24}\)) 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 \(^\text{25}\)).

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 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:

<table>
<thead>
<tr>
<th>Normal evolution</th>
<th>PI</th>
<th>RI</th>
<th>SDR</th>
<th>Graft volume</th>
<th>Serum creatinine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normality</td>
<td>*14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tubular necrosis</td>
<td>*15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*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.

*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.

*21: Table 3. Correlations* between Doppler indices and serum creatinine level 12 days assessment.
"22: Table 4. Correlations* between Doppler indices and serum creatinine level 20 days assessment.

<table>
<thead>
<tr>
<th>Evolutions</th>
<th>PI - creatinine</th>
<th>RI - creatinine</th>
<th>SDI - creatinine</th>
<th>Creatinine volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>0.073</td>
<td>0.039</td>
<td>0.376</td>
<td>0.410</td>
</tr>
<tr>
<td>Nephrototoxicity</td>
<td>0.022</td>
<td>0.016</td>
<td>0.070</td>
<td>0.535</td>
</tr>
<tr>
<td>Tubular necrosis</td>
<td>0.070</td>
<td>0.041</td>
<td>0.399</td>
<td>0.488</td>
</tr>
<tr>
<td>Rejection</td>
<td>0.009</td>
<td>0.006</td>
<td>0.238</td>
<td>0.002</td>
</tr>
<tr>
<td>Renal dysplasia</td>
<td>0.033</td>
<td>0.045</td>
<td>0.376</td>
<td>0.008</td>
</tr>
</tbody>
</table>

* Correlations are significant if p < 0.05

"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.

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

<table>
<thead>
<tr>
<th>Author</th>
<th>n</th>
<th>RI (95% CI)</th>
<th>PI (95% CI)</th>
<th>Graft Donor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merkus et al [1]</td>
<td>123</td>
<td>0.46-0.69</td>
<td></td>
<td>cadaveric</td>
</tr>
<tr>
<td>Merkus et al [1]</td>
<td>20</td>
<td>0.46-0.64</td>
<td></td>
<td>living-related</td>
</tr>
<tr>
<td>Frauchiger et al [2]</td>
<td>14</td>
<td>0.62-0.74</td>
<td>1.13-1.69</td>
<td>not specified</td>
</tr>
<tr>
<td>Johnson et al [3]</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salgado et al [4]</td>
<td>37</td>
<td>0.84-1.03</td>
<td></td>
<td>cadaveric</td>
</tr>
<tr>
<td>Don et al [5]</td>
<td>34</td>
<td>0.58-0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Don et al [5]</td>
<td>32</td>
<td>0.54-0.66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schwallhofer et al [6]</td>
<td>35</td>
<td>0.59-0.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Krumme et al [7]</td>
<td>110</td>
<td>0.63-0.77</td>
<td>1.15-1.57</td>
<td>not specified</td>
</tr>
</tbody>
</table>

* means ± sd
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. Moreover, 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

The Authors


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
Keywords

MeSH-Keywords:
E02.870.500
Kidney Transplantation

E01.370.350.850.850
Ultrasonography, Doppler

D03.383.374.207
Creatinine

U.S. National Library of Medicine is the creator, maintainer, and provider of all MeSH 2004 data.

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS™ by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR’s endorsement, sponsorship or recommendation of the third party, information, product, or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys’ fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.ecr.org