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Renal vascular resistance in patients with chronic renal failure

Ingrid Prkačin, Nives Dabo, Iva Palčić, Boris Brkljačić, Mirjana Sabljar-Matovinović, Zdravko Babić

[1]*Departments of Internal Medicine and Radiology, Merkur University Hospital, Zagreb, Croatia*

Background. *Duplex Doppler sonography has the potential to provide physiological information concerning renal arterial blood flow and resistance. The purpose of the study is to evaluate duplex Doppler sonography for assessing renal vascular resistance (RVR) in patients with chronic renal failure.*

Materials and methods. *Resistive indices (RIs) and pulsatility indices (PIs) were measured in the intrarenal arteries of 30 patients with chronic renal failure and 20 control subjects. RIs and PIs of control subjects were compared to those of the patients with chronic renal failure and correlated with the laboratory and clinical findings.*

Results. *In the control subjects, the mean RI was 0.59±0.03 (±SD) and mean PI was 1.00±0.11. In the patients with chronic renal failure, the mean RI was 0.71±0.11 and mean PI was 1.69±0.21. Elevated RIs and PIs were associated with the progression of renal failure. Statistically significant ($p<0.001$) correlations were observed between both, RI and PI, and the serum creatinine level, creatinine clearance rate, and systolic and diastolic blood pressure measurements.*

Conclusion. *Doppler indices reflect an increased RVR in the patients with chronic renal failure and correlate with the laboratory and clinical parameters, whereas RI and PI measurements offer no advantages over these parameters to predict the disease progress.*

Key words: kidney failure, chronic; renal artery-ultrasonography; vascular resistance

Introduction

Sonography is routinely performed to evaluate the patient with suspected or known renal disease. Although gray-scale sonography can provide important anatomic information, it lacks the ability to provide significant physiological data. Duplex Doppler sonography has the potential to provide physiological information concerning renal arterial blood flow and resistance.[1-3] Doppler study of small intrarenal vessels, although not difficult, requires a proper technique to obtain useful measurements.[3,4] Most investigators have concentrated on the study of distal intrarenal vessels, which are not actually seen during the examination but are detected by sampling the Doppler spectrum at the corticomedullary

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Correspondence to: Ingrid Prkačin, M.D., M.Sc., Department of Internal Medicine, Merkur University Hospital, Ul. I. Zajca 19, 10000 Zagreb, Croatia. Phone: + 385 1 2431 390/454; Fax:+ 385 1 2431393

junction or along the borders of the medullary pyramids.[5] A study by Knapp (1995) of 120 subjects found the resistive index (RI) measurements to be most consistent at the level of the interlobar-arcuate arteries.[4]

Most investigators have used RI to characterize the intrarenal Doppler wave form.[5-8] These easily calculated parameter is defined as RI=(Peak Systolic Shift-Minimum Diastolic Shift)/Peak Systolic Shift. Increases in downstream resistance result in a relative reduction of diastolic flow compared with the systolic flow and elevation of the RI. Hence, RI can be used as an estimate of renal arterial resistance.[4] Several studies have investigated normal intrarenal RI values; the majority suggest 0.70 as a reasonable upper limit for the normal RI.[4,9,10] Conditions other than intrinsic renal disease can also affect the RI. A significant hypotension, markedly decreased heart rate, and perinephric or subcapsular fluid collection can elevate the RI.[11-13] In this study, the authors hypothesize that Doppler sonographic indices that are measured in intrarenal arteries will reveal the changes of RVR in patients with renal failure.

Patients and methods

Patients

The investigated group comprised 30 patients (mean age 51.4 years) with chronic renal failure (glomerular or tubulointerstitial diseases, nephroangiosclerosis). The criteria for diagnosing chronic renal failure were: (1) Azotemia for > 3 months, (GFR- glomerular filtration rate is about 20 to 35 percent of normal); (2) Prolonged symptoms or signs of uremia; (3) Symptoms or signs of renal osteodystrophy; (4) Kidneys reduced in size bilaterally.

The patients with chronic renal failure have glomerular disease (N=9) (primary glomerular disease (N=7), such as focal segmental glomerulosclerosis, membranous glomerulo nephropathy, membranoproliferative glomerulonephritis and multisystem diseases (N=2), such as systemic lupus erythematosus), tubulointerstitial disease (N=11) and nephroangiosclerosis (N=10).

The patients with a history of heart disease or diabetes mellitus, as well as all patients with conventional US findings of renal calculi, collecting system dilatation, or suspected expansive processes were excluded from the study.

The control subjects were 20 healthy volunteers, mean age 49.3 years. RIs and PIs of control subjects were compared with those of the patients with chronic renal failure.

Methods

Real-time and color duplex US examinations were performed using a color Doppler scanner (Radius CF, general Electric Medical Systems), with a 3.75 MHz curved-array transducer. Pulsed Doppler US studies of the segmental, interlobar and arcuate arteries were performed in both kidneys in each patient. The segmental, interlobar and arcuate arteries were distinguished with respect the position of the Doppler sample volume for the inner kidney zone (renal sinus), middle zone (corticocentral boundary) and outer zone (corticomedullary border). RI was measured according to the following formula (peak systolic frequency shift-minimum diastolic frequency shift)/ peak systolic frequency shift. The PI was measured with the formula: (peak systolic frequency shift-minimum diastolic frequency shift)/mean frequency shift during the whole cardiac cycle.

All control subjects and patients were examined in the supine and semioblique positions; they had to suspend respiration for 10 seconds so that a representative spectra could be obtained.

For all patients, laboratory findings for the presence of proteinuria and serum creatinine levels and creatinine clearance rates were available. Normal values for serum creatinine and creatinine clearance are 62-124 mikro-

mol/L (Jaffe method) and 1.2-2.4 ml/sec, respectively.[14] In healthy adults, urinary protein excretion, as measured in the 24-hour urine specimen, is up to 150 mg. Mild protein excretion is referred to as low-grade proteinuria when urinary protein excretion is less than 1 to 2g/24 h, whereas the excretion of 3.5g/24 h or more is defined as nephrotic range proteinuria.[15]

Doppler sonographic indices were correlated with systolic and diastolic blood pressure values, which had been measured prior to US examination. The interval between US examination and blood or urine sampling for laboratory examination was less than 5 days in all cases. All laboratory examinations were performed in the same laboratory.

Results

Mean RI in the control subjects and in the patients with chronic renal failure was 0.59±0.03 (±SD) and 0.71±0.11, ($p<0.01$), respectively. Mean PI in the controls and in the patients with chronic renal failure was 1.00±0.11 and 1.69±0.21, ($p<0.01$), respectively. The patients with chronic renal failure were classified by RI values into two groups. Group I included 15 patients with normal RI, mean age 43.7 years. Group II was composed of 15 patients with elevated RI (more than 0.70), mean age 63.4 years. Of the 30 patients with chronic renal failure (50%), 12 of whom were found to be hypertensive (blood pressure>140/90mmHg), an elevated RI was noted in 15 patients. Mean values of systolic and diastolic blood pressure were 160±15mmHg and 105±13mmHg, respectively. An RI <0.70 was observed in the remaining 15 patients of the 30 (50%), of whom 12 were normotensive. In hypertensive patients, mean RI and mean PI were 0.74±0.12 and 1.90±0.20, respectively. In the normotensive patients, mean RI and mean PI were 0.64±0.09 and 1.19±0.32, respectively. The statistical significance of RI and PI differences in normotensive and hypertensive patients with chronic renal failure was calculated to be $p<0.02$ and $p<0.04$, respectively.

In the patients of group I, who were younger (mean 43.7 years), glomerular disease was present in 60% (N=9) of patients, and tubulointerstitial diseases in 40% (N=6). In 86% of these patients, the creatinine clearance rate was higher than 0.25ml/sec, and in 10 patients, proteinuria was lower than 3g/l. In the patients of group II, who were older (mean 63.4 years), nephroangiosclerosis was present in 66.6% (N=10) of patients, and tubulointerstitial diseases in 33.3% (N=5) of patients. In 80% of the patients of group II, the creatinine clearance rate was lower than 0.25 ml/sec, and proteinuria was higher than 3g/l in 8 patients.

Discussion

Normal RI values have been established in native kidneys, and the cut off value of 0.70 or greater is generally considered to represent an abnormal RI.[16] The age was shown to be an important variable that affected RI values as well as arterial hypertension.[5] A highly significant correlation was found between the RI, the serum creatinine levels and creatinine clearance rates in patients with diabetic nephropathy and several other parenchymal diseases, particulary those affecting the tubulointerstitial and vascular compartments of the kidney.[5,16] Our results show that Doppler indices do accurately reflect an elevated RI, especially in the patients with the creatinine clearance rate of less than 0.25ml/s ($p<0.001$). RI has been found to correlate with renal function much better than PI.

Based on the results of our study, an elevated RI appears to reflect progression of renal failure, while hypertension without TOD (target organ damage) does not seem to affect RI.

Studies suggest that RI elevation is more likely to occur with a vascular or tubulointerstitial renal process, and is much less likely with the disease limited to the glomeruli.[3] Furthermore, RI is not a measure of renal function per se, but rather reflects renal vascular resistance. When an elevated renal arterial resistance accompanies abnormal renal function, RI is more closely related to renal function, especially in diabetes mellitus.[3,5,6,17] Conversely, some renal pathology causes a significant loss of renal function with little or no change in renal vascular resistance. In these instances, RI does not reflect the loss of renal function.[14] In patients with chronic renal disease, RI is closely related to certain haemodynamic and functional parameters.[10,17]

The drawback of the present study is a relatively small number of patients studied. Moreover, it was not designed in a longitudinal fashion as each patient was examined only once by duplex Doppler US. Furthermore, it is not surprising that the disease with a destructive and deformative effect on the renal parenchyma increases RI. Therefore, measuring RI and PI alone cannot alter the patient's outcome. However, a good correlation between RI and renal functional parameters on the one hand and the development of arterial hypertension in the patients with chronic renal failure, on the other, that was observed in our study, may eventually prove that duplex Doppler US could be used as an additional parameter in the assessment of severity of chronic renal failure.

In conclusion, color duplex Doppler US in intrarenal arteries proved to be useful in the assessment of increased RI in chronic renal failure patients. Elevated RI and PI heralded the progression of renal failure. Doppler indices correlated significantly with renal function tests. However, additional longitudinally designed studies on a larger patient group will be necessary to evaluate in full the clinical usefulness of duplex Doppler US in patients with chronic renal failure.

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