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Age-related changes of renal vascular resistance in normal native kidneys: color duplex Doppler ultrasound assessment

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Purpose: To evaluate age-related changes of renal vascular resistance (RVR) in normal native kidneys. Materials and methods. Intrarenal arteries were insonated in 180 kidneys of 90 examinees and Doppler sonographic resistive indexes (RIs) were measured. Examinees were classified into three age groups: the first consisted of subjects < = 30 years old, the second of subjects between 31 and 54 years and the third of subjects 55 years of age and older.
Results: Mean RIs were 0.57 in the first group, 0.598 in the second group, and 0.621 in the third group. RIs were found to be age dependent, with significant elevation observed with increasing age (group I vs. group II, P < .01; group II vs. group III, P = .03; group I vs. group III, P < .01).
Conclusion: Doppler sonographic resistive indexes reflect elevation of RVR with aging.

Key words: kidney, blood, renal artery-ultrasonography; ultrasonography, supply, Doppler, color; age factors.

Introduction

Extensive research has been performed during the last decade in Doppler assessment of intrarenal blood flow in transplanted kidneys.[1–3] In the last few years Doppler studies were performed in native kidneys, as well.[4–6] Normal values have been established in a few studies and Doppler indexes have been correlated with renal functional tests and blood pressure values in several renal diseases.[7–13] In most of these studies age-dependent changes of renal vascular resistance were neglected, although some authors referred to age-related changes of Doppler inexes in large series of patients.[10] The purpose of this study was to evaluate age-related changed of renal vascular resistance, reflected in values of Doppler sonographic resistive indexes (RIs), in normal native kidneys.

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Materials and methods

Between November 1991 and November 1994 color-duplex Doppler sonography of intrarenal arteries was performed in 180 kidneys of 90

subjects without renal impairment. There were 39 men, and 51 women, aged 18–55 years (mean 44.6 ± 14.6 years). Twenty six were healthy volunteers and 64 were studied in the course of nonrenal abdominal, thyroid or breast US examinations. The inclusion criteria for the examination were abscence of a history of kidney disease; absence of systemic, chronic or malignant diseases that might affect renal function; absence of hypertension; absence of history of congenital or acquired heart disease; normal conventional US finding of kidneys; and normal urinalyisis findings prior to Doppler US examination. Twenty eight subjects had findings of normal serum creatinine, tested within 30 days prior to Doppler US examination. Informed consent was obtained from all examinees. All subjects were older than 18 years, to avoid variations in RIs values noted in childhood.[14,15] The examinees were arbitrarily classified into three age groups (< = 30 years old, 31–54 years, > = 55 years) to evaluate age dependence of RI values in healthy adult subjects.

Real-time and color duplex-Doppler US examinations were performed with a Radius CF color Doppler scanner (GE-CGR, Buc, France), with a curved-array 3.75-MHz transducer. After color-Doppler identified flow in intrarenal vessels, a sample-volume was positioned in segmental, interlobar and arcuate arteries in their typical positions. Spectral analysis was performed and RIs measured using existing software capabilities of the scanner. Mean RI values for each kidney were calculated from all measurements. Wall-filter of 50 Hz and minimal PRFs were used to obtain optimal spectral waveforms in all cases. Sample-volume was set at 2–4 mm. Examination was technically successful and adequate spectra obtained in all subjects. The RI was measured with the formula (peak systolic frequency shift – minimum diastolic frequency shift)/mean frequency shift during the cardiac cycle.[16] Subjects were examined in supine and decubitus positions; the duration of the examination per person was 30–40 minutes. All the examinations were performed by the first author (B. B).

Mean RI values were compared between different age groups of examines. "Goodness-of-fit test" (Kolmogornov-Smirnov) was used to test whether the distribution of RI values was normal. The statistical significance of observed differences was calculated with the Mann-Whitney U test. The Pearson method was used to estimate the correlation between RIs and age of the age of the whole group of examinees.

Results

The mean RI ± SD in 180 kidneys of 90 subjects with normal native kidneys was 0.596 ± 0.038 (range 0.535 – 0.685). All RIs were below 0.70.

There were 23 examinees 30 years old or younger (group I), 46 subjects were in the range of 31 – 54 years of age (group II), and 21 examinees were 55 years old or older (group III). The distribution of RIs by these three age groups is shown in Figure 1.

The age distribution, as well as distribution of RIs within each age group was normal. Statistical significance of differences of RIs between different age groups (Mann-Whitney U-test) was observed between the age groups I and II ($P < .01$), between the age groups II and III ($P = .03$; 95 % confidence level), and between the age groups I and III ($P < .01$).

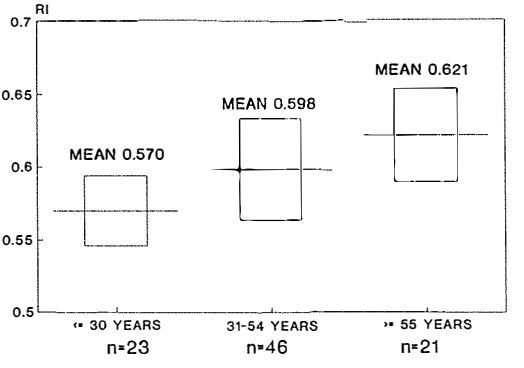

Figure 1. The distribution of mean RI values and 1 S. D. in three age-groups of examinees with normal native kidneys. n = number of patients within the particular age-group.

The typical Doppler spectra from intrarenal arteries with high continuous diastolic flow and low resistive index are shown in the Figure 2.

The Pearson lienar correlation method showed high and statistically significant correlation between RIs and age of the whole group of examinees with normal native kidneys. The Pearson correlation coefficient (r) between age of examinees and RI was 0.5172 ($P < .001$).

The Pearson method showed lack of correlation between RIs and renal length and between RIs and renal parenchymal thickness in subjects with normal native kidneys. Correlation coefficients between RIs and renal lenght were: $r = -0.053$ for the right kidney ($P = NS$) and $r = -0.061$ for the left kidney ($P = NS$). Coefficients between RIs and renal parenchymal thickness were: $r = -0.078$ for the right kidney and $r = -0.086$ ($P = NS$) for the left kidney ($P = NS$).

Discussion

Doppler sonographic studies of renal vascular resistance in renal parenchymal diseases have shown complex interrelations of several parameters affecting values of Doppler sonographic indexes.[10,17] A few studies have analyzed relation between RI and renal biopsy findings. It appears that the site of the pathologic alterations within the kidney is very important in measurement and interpretation of Doppler sonographic indexes.[13,18] Doppler analysis seems to be particularly useful in disease affecting tubulointerstitial and vascular compartments of kidneys. In diabetic nepropathy Doppler indexes reflect elevated renal vascular resistance.[10,17] In unilateral pyelocalicectasis Doppler seems to be very accurate in distinguishing between obstructive and non-obstructive collecting system dilatation.[11,12] In addition to pathologic alterations within the kidney and hypertension, age has emerged in large studies as a significant covariable, affecting RVR and Doppler indexes values.[10,17] The present study has shown a high and significant correlation of Doppler sonographic resistive index and age of examinees with normal native kidneys. It has also shown age-dependance of RIs values, which tend to increase with aging.

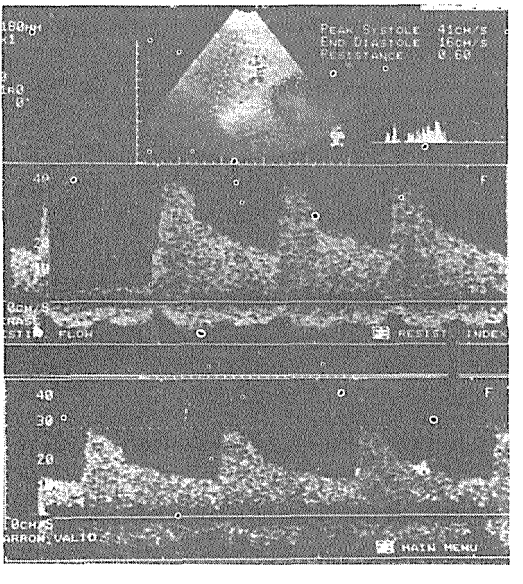

Figure 2. The normal spectral waveforms of intrarenal arteries in normal native kidney; continuous high diastolic flow with low resistive index.

In a literature a RI value of 0.70 has been generally accepted as a threshold value for pathological renal vascular resistance, and RIs of 0.70 and higher are considered abnormally elevated. This threshold RI value has been introduced by Platt[5,17,18] and other groups of investigators have accepted it.[10–13] This study has shown that it is reasonable to take into account age-related dependence of Doppler indexes in interpretation of their values and in comparison with the control groups.

Statistically significant differences of RIs values were observed in the present study between arbitrarily chosen age-groups of examinees. It was noted that all the examinees had RIs below 0.70, and even in the oldest age-group the mean RI of 0.621 was far below the threshold value of 0.70. The mean RI value of 0.596 ± 0.038 observed in this study was similar to other studies where mean intrarenal RIs in normal native kidneys ranged from 0.58 to 0.64.[5,7,9,10]

There are several limitations in the golden standard reference method for normal renal

status. It is known that serum creatinine levels may be normal while even a 50% decrease in renal function may exist simultaneously.[19] Therefore, it is hard to prove normal renal status when a study is performed in a usual clinical setting. An analysis of creatinine clearance rates has to take in account potential error from inaccurate urine collection.[19] In the present study, small proportion of control subjects had serum creatinine levels tested and we had to rely in the majority of subjects on absence of history of renal disease, normal conventional US findings and urin analysis findings for inclusion of examinees in the control group. Although some persons with renal functional impairment may have been included in the control group using such criteria, we believe that the relevance of obatined data is not essentially decreased.

This study shows that elevation of RIs with aging does not represent false variations or variability of these values. A few studies about physiology of aging suggest that the loss of renal function related with aging is hemodinamically mediated (elevated renal vascular resistance).[20–23] The present study confirms those results. Some authors think that elevation of Doppler indexes that occurs with aging reflects the loss of functioning nephrons, observed in the senescent kidney, that is not reflected by serum creatinine elevation.[5,19,24] In pediatric population higher RIs were observed in comparison with adults.[14,5] Only subjects older than 18 years were included in the present study, so the changes of RIs in childhood need not to be accounted for. RIs values did not show significant correlation with renal length and parenchymal thickness of our examinees, which is not surprising for normally functioning kidneys.

Doppler US imaging has the most important potential for the diagnosis of parenchymal renal diseases in the longitudinal follow-up of patients with renal disease to provide predictive clinical information on the recovery of renal function or the progression of renal disease. Results of the present study indicate that elevation of RIs with increasing age has to be taken into account in such longitudinal studies, and that it is acceptable to consider RI of 0.70 as a threshold value for pathologic elevation of renal vascular resistance.

References

1. Pelling, M, Dubbins PA. Doppler and color Doppler imaging in acute transplant failure. *J Clin Ultrasound* 1992; **20;** 507–11.
2. Deane C. Doppler and color Doppler ultrasonography in renal transplants: chornic rejection. *J Clin Ultrasound;* **20**: 539–42.
3. Becker JA. Role of radiology in evaluation of the failing renal transplantation. *Radiol Clin North Am* 1991; **29:** 511–5.
4. Sauvain JL, Bourscheid D, Pierrat V, et al. Duplex Doppler ultrasonography of intra-renal arteries. Normal and pathological aspects. *Ann Radiol 1991;* **34;** 237–46.
5. Platt JF. Duplex Doppler evaluation of native kidney dysfunction: obstructive and nonobstructive disease. *AJR* 1992; **158:** 1035–42.
6. Scheidegger JR, Werlen S. Spektral und Farbdopplersonographie: Technik, Moglichkeit und Grenzen in der Uroradiologie. *Schweiz Med Wochenschr; 1991;* **121** (9): 292–8.
7. Gottlieb RH, Luhmann K IV, Oates RP. Duplex ultrasound evaluation of normal native kidneys and native kidneys with urinary tract obstruction. *J Ultrasound Med* 1989; **8:** 609–11.
8. Rodgers PM, Bates JA, Irving HC. Intrarenal Doppler ultrasound studies in normal and acutely obstructed kidneys. *Br J Radiol* 1992; **65:** 207.
9. Kim SH, Kim WH, Choi BI, et al. Duplex sonography of the native kidney – Resistive index vs. serum creatinine. *J Ultrasound Med* 1990; **9:** 25–9.
10. Brkljačić B, Mrzljak V, Drinković I, Soldo D, Sabljar-Matovinović M, Hebrang A. Renal vascular resistance in diabetic nephropathy: duplex Doppler US evaluation. *Radiology* 1994; **192:** 549–54.
11. Brkljačić B, Drinković I, Sabljar-Matovinović M. et al. Intrarenal duplex-Doppler sonographic evaluation of unilateral native kidney obstruction. *J Ultrasound Med 1994:* **13:** 197–204.
12. Brkljačić B, Drinković I, Soldo D, Vidjak V, Odak D, Hebrang A. Pulsedwave and color-Doppler in the assessment of native kidneys with urinary tract obstruction. *Radiol Oncol* 1993: **27:** 21–6.
13. Mostbeck GH, Kain R, Mallek R, et al. Duplex Doppler sonography in renal parenchimal disease. Histopathologic correlation. *J Ultrasound Med* 1991; **10** (4): 189–94.

14. Wong SN, Lo RNS, Yu ECL. Renal blood flow pattern by non-invasive Doppler ultrasound in normal children and acute renal failure patients. *J Ultrasound Med* 1989; **8:** 135–43.

15. Keller MS. Renal Doppler sonography in infants and children. *Radiology* 1989; **172:** 603–4.

16. Pourcelot L. Applications cliniques de l'examen Doppler transcutane. In Peronneau P ed *Velocimetrie ultrasonare Doppler Seminaire INSERM.* Paris, 1974; **34:** 213–30.

17. Platt JF, Rubin JM, Ellis JH. Diabetic nephropathy: evaluation with renal duplex Doppler US. *Radiology* 1994; **190:** 343–6.

18. Platt JF, Ellis JH, Rubin JM, Di Pietro MS, Sedman AB. Intrarenal arterial Doppler sonography in patients with nonobstructive renal disease: correlation of resistive index with biopsy findings. *AJR* 1990; **154:** 1223–7.

19. Becker JA Evaluation of renal function. *Radiology* 1991; **179:** 337–8.

20. Hollenberg NK, Adams DF, Solomon HS, Rashid A, Abrams HL, Merrill JP. Senescence and the renal vasculature in normal man. *Circ Res* 1974; **34:** 309–14.

21. Epstein M. Effects of aging on the kidnes. *Fed Proc* 1979; **38:** 169–72.

22. Anderson S, Brenner BM. Effects of aging on the renal glomerulus. *Am J Med* 1986; **80:** 435–42.

23. Cody RJ, Torre S, Clark M, Pondolfino K. Age-related hemodynamic, renal and hormonal differences among patients with congestive heart failure. *Arch Intern Med* 1989; **149:** 1023–8.

24. Riehl J, Clasen W, Schmitt H, Kierdorf H, Siebert HG. Altersabhaengige veraendenrungcn der renal haemodynamik. Untersuchungen untells duplex-sonographie (DS). *Ultraschall Klin Prax* 1989: **4**(1): 129.