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Evaluation of intrarenal arterial Doppler spectra in healthy children

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Background. *The aim of the study was to determine the features of intrarenal arterial Doppler spectra in healthy children by measuring acceleration time (AT) and resistance index (RI).*

Subjects and methods. *RI and AT values were compared between different age-groups of children and with normal RI values in adult population. Color duplex Doppler sonography of the intrarenal arteries, using Acuson 128XP10 scanner, was performed in 150 children (300 kidneys), with no clinical or laboratory pathological changes of the urinary tract. All children were classified into three age groups: (1) 52 children between 2 to 6 years of age; (2) 48 children from > 6 to 11 years of age; (3) 50 children from >11 to 16 years of age.*

Results. *The mean RI +/- 1.S.D. value in the group I was 0.70 +/- 0.03, in the group II 0.625 +/- 0.025 and in the group III 0.585 +/- 0.03. AT ranged from 0.04-0.09 seconds and the mean value of 0.07 +/- 0.01 seconds was the same for all three groups.*

Conclusions. *RI in early childhood is considerably higher as compared to older children and the adult population; after the age of six, RIs become equal to those in the adults. The utilization of RI=0.70, as a threshold value for the increased renal vascular resistance in adults, can be also applied to children over 6 years. The detection of renal artery stenosis on the basis of the analysis of acceleration time is the same in children and in adults.*

Key words: renal artery-ultrasonography; colour Doppler imaging; child

Introduction

Duplex Doppler ultrasonography has been extensively used in the last few years in the assessment of various kidney diseases in adults and children. In pediatric nephrology, Doppler was first used to evaluate vascular changes in renal transplants, especially to detect renal artery stenosis and trans-

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plant rejection.[1-6] In the native kidneys, Doppler was used for the detection and follow up of hemolytic-uraemic syndrome, diagnosis of renal artery stenosis and renal vein thrombosis, detection of focal ischaemic areas in acute inflammation or infarction, and for the assessment of perfusion in renal insufficiency and several parenchymal diseases.[7-14]

Renal Doppler enables a non-invasive evaluation of renal vascular resistance, by measuring resistance index (RI) and other Doppler sonographic indices in the intrarenal arteries. It is especially important for the evaluation of blood flow in renal parenchymal diseases. Several studies in children and adults showed that an increased RI can be found in various parenchymal kidney diseases (hemolytic-uremic syndrome, interstitial nephritis, diabetic nephropathy, autosomal dominant polycystic disease, etc.), while in glomerulonephritis, the RI values are normal.[14-17] The detection of renal artery stenosis is based on the rise of flow velocity in the main renal artery and changes in the morphology of Doppler spectra in the intrarenal arteries, distally of the site of stenosis, particularly the changes of the acceleration time.[18-21] In order to interpret the changes of the Doppler spectra in all these pathologic conditions in pediatric nephrology, the normal morphologic features of intrarenal arterial Doppler spectra in healthy children have to be determined.

In this study, we analyzed the features of intrarenal arterial Doppler spectra in healthy children and measured acceleration time and resistance indices. The children were divided into several age groups in order to evaluate age-dependence of RI since it is known that the RI values in adult population are age-dependent.[22] The RI values in children were also compared with the normal RI values in adult population to determine the age at which RI in children reaches the values of the adults.

Materials and methods

Between December, 1996 and March, 1998, color duplex sonography was performed in 150 children (300 kidneys) with no clinical or laboratory pathological changes of the urinary tract. The criteria for the inclusion into the study were: normal urinalysis findings prior to US examination, normal B-mod US finding of both kidneys, absence of history of kidney diseases, hypertension, congenital or acquired heart disease, any chronic or metabolic disease. All children were classified arbitrarily into three age groups: (1) 52 children between 2 to 6 years; (2) 48 children > 6 to 11 years; (3) 50 children > 11 to 16 years. Of these, 74 were boys and 76 girls. They were recruited from a group of children undergoing ultrasound examinations for unrelated organ systems, without significant abnormality found in the area of original interest. Sixteen children were volunteers. Informed consent was obtained from the parents of all children.

Real time and color duplex US examinations were performed with a color Doppler scanner Acuson 128 XP10, with a curved-array 5-MHz transducer. All children underwent examination with conventional US; the length of the kidney and the thickness of the renal parenchyma were measured. During the examination, the children were in supine or lateral decubitus position. Color Doppler US studies of the interlobar and arcuate arteries were performed in both kidneys in each child. The Color identification of the intrarenal arteries considerably facilitated the positioning of the Doppler sample volume and examinations were performed at the lowest possible angle between the ultrasonic beam and the insonated vessel. Recordings were obtained in at least three different vessels from the upper, middle and lower third of the kidney. From each recording RI and acceleration time (AT) were measured only when at least three consecutive waveforms with simi-

lar appearance were noted. RI was measured with the following formula: (peak systolic frequency shift - minimum diastolic frequency shift / peak systolic frequency shift). AT was measured by positioning the caliper to the point of the beginning of the cycle and to the point of the maximum systolic velocity. The distance between these points represented the AT value. The wall filter was set at the lowest value of 50 Hz, and the Doppler sample volume was set at 1-3 mm. The minimal pulse repetition frequencies that did not produce alliasing were used. Only optimal spectral waveforms for a particular vessel were used for measurement. Measurements were obtained with the existing software capabilities of the scanner. Mean RI and AT were calculated from all measurements in each kidney. The RI and AT value differences between the right and left kidneys in the same child were also analyzed. For the comparison of the RI values in children with normal adults, the results from Brkljačić *et al.*[22] were used, where the age dependence and RI values in the intrarenal arteries in healthy adults were analyzed. The average duration of the examination per child was 30 minutes. Adequate spectral waveforms were obtained in all children. All examinations were performed by the first two authors. The mean values of measured parameters were used for the statistical analysis of differences between the groups of examinees. The statistical analysis was carried out with "SPSS/PC+". The statistical significance of observed differences was calculated with the nonparametric Mann-Whitney U-test. Standard descriptive statistic parameters were also used for the presentation of our results.

Results

Doppler sonography was successful in all the 300 kidneys of 150 children (74 boys and 76 girls) examined. All children complied with the prior described criteria for the inclusion into the study.

The distribution of RI +/- 1.S.D. by the age-groups is shown in the Figure 1. In order to compare the RI values in children with those in healthy adults, we added to the figure also the RI values in adults from the study of Brkljačić *et al.*[22]

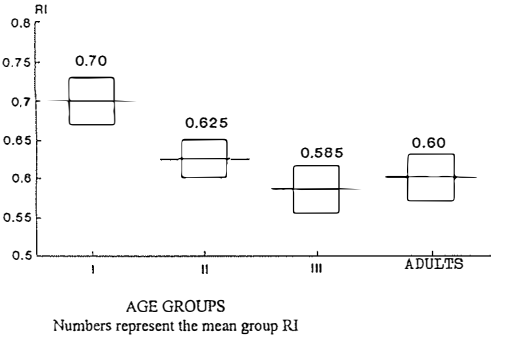

Figure 1. The distribution of RI by age groups.

The mean RI +/- 1.S.D. value in the group I was 0.70 +/- 0.03 (range 0.64-0.75), which is statistically significantly higher as compared to the group II (RI 0.625 +/- 0.025; range 0.575-0.655) and the group III (RI 0.585 +/- 0.03; range 0.55-0.65).

The statistical significance of the RI differences between age groups was tested. P values and the presence or absence of significance of the differences is presented in Table 1.

Table 1. Statistical significance of RI differences between age groups

Age-groups	p	Statist. significance
I vs. II	< 0,01	+
I vs. III	< 0,01	+
II vs. III	< 0,03	+
I vs. adults	< 0,01	+
II vs. adults	< 0,03	+
III vs. adults	> 0,10	-

In the group of the youngest children (group I, up to six years), the RI values were

significantly higher in comparison with the other groups of children and the adult group. In the group II (>6-11 years) the RI values were just slightly higher than in the adult group, with the statistical significance of differences in the level of only 95%. In the Figure 1, an overlap of many values can also be noted between this group (II) and the adult group, while there is practically no overlap in the RI values between the adults and the youngest children group (I). In the third group of children (> 11 years of age), no difference was observed in comparison with the adults.

To establish whether a threshold value of 0.70 of the adults can be used in children as well for the evaluation of higher renal vascular resistance, the ranges of RIs in children age groups were analyzed in intervals of 0.05, and the results are presented in Table 2.

Table 2. Ranges of RI values in age groups of children

Range of RI	Group I (N=52)	Group II (N=48)	Group III (N=50)
0,55-0,59	0	4 (8,3%)	6 (12%)
0,60-0,64	7 (13,5%)	32 (66,7%)	35 (70%)
0,65-0,69	8 (15,4%)	12 (25%)	9 (18%)
0,70-0,74	29 (55,8%)	0	0
>= 0,75	8 (15,4%)	0	0

These results indicate that RI is below 0.70 in all children over 6 years in the groups II and III. However, in younger children (group I), the RI>= 0.70 was observed in as much as 67.3% (35 of 52) children. Therefore, one can conclude that the threshold RI value of 0.70 in this age group is not an acceptable indicator of higher renal vascular resistance.

The measured acceleration time (AT) ranged from 0.04-0.09 seconds with very small variability, and the mean value was the same for all three groups: it was 0.07+/ 0.01 sec.

Discussion

Duplex Doppler ultrasonography of the intrarenal arteries enables non-invasive evaluation of renal vascular resistance and measurement of velocities in the renal and intrarenal arteries. Doppler findings have a considerable significance in adults and children in the diagnosis of renal artery stenosis, renal vein thrombosis, complications after kidney biopsy, evaluation of blood flow in acute and chronic kidney inflammation, distinction of obstructive and non-obstructive collecting system dilatation and in evaluation of renal vascular resistance in various parenchymal renal diseases (e.g. diabetic nephropathy, lupus, autosomal dominant polycystic kidney disease (ADPKD), hepatorenal syndrome, hemolytic-uremic syndrome, interstitial nephritis).[23-26] The longitudinal measurements of RI can be useful in predicting the normalization of renal function or progression of renal functional impairment. Doppler can be useful in the evaluation of vascularization in benign and malignant renal masses.[27] Power Doppler has been shown to be particularly useful for the detection of focal inflammatory changes in the kidneys and focal renal ischaemic areas.[27,28]

Several studies have been conducted in the adult population for the assessment of Doppler in various kidney diseases. One of the most important findings was the observation by Platt *et al.*[26] that the RI value below 0.70 can be used as an indicator of normal

renal vascular resistance in adults. The age-dependence of the RI values in the adults was observed, with RI rising in older age; this is manifested as a loss of the functioning nephrons and increase in renal vascular resistance, which is not detected from the changes of serum creatinine values. The RI values greater than 0.70 can be interpreted as a sign of elevated renal vascular resistance and can be found in several parenchymal renal diseases and some other conditions. However, in several reports, the RI values higher than 0.70 were reported in the intrarenal arteries of healthy children.[29-35] This is the reason for a limited and only lately growing use of Doppler techniques in children. In order to compare the RI values in children with those in healthy adults, we have compared our results with the results of the study published by Brkljačić *et al.*[22] They examined a group of 121 healthy adult examinees with normal kidney function (51 men and 70 women, age-range 19-83 years, mean age 44.1 +/- 14.8 years), in which the Doppler analysis of the intrarenal arteries was performed in the same way as in this paper. In that study on healthy examinees, the mean RI of 0.60 +/- 0.035 (range 0.535-0.685) was determined. The normal RI values in the literature ranged from 0.58 to 0.64; they were obtained with different examination techniques and number of examinees. We consider the given values in the adults to be adequate for the comparison with the results in this study because the examination was performed under identical technical conditions, using the same type of color Doppler scanner and with the same number of measurements in the kidneys.

The normal range of renal Doppler findings in children has not been extensively studied yet. Earlier studies found no age dependence of renal RIs in children,[36] but later ones reported that the renal vascular resistance changed with age. The recognition of abnormal renal RIs in children and interpretation of measured RI values, therefore, require the knowledge of normal RIs in children. Our data indicate that renal RIs in children under six years are above the level of the adult values. In older children, the RI values do not differ significantly from those in adults; in healthy children older than six years, RI is always under 0.70. Therefore, the RI values in children over 6 years can be interpreted in the same fashion as in adults while, in younger children. RIs should be interpreted according to the normal values of the particular age groups.

Increased RIs in young children are due to higher renal vascular resistance in the maturing human kidney. Renal functional parameters, like glomerular filtration rate, tubular excretory capacity and blood rate are decreased in newborns and mature by the first year. The higher activity of the renin-angiotensin system in infancy and childhood in comparison with the values in adults has been studied in detail. Plasma renin activity (PRA) in full-term infants is about 10 ng/ml/hour; it decreases during the first year of life to 5 ng/ml/hour, and the value of 1 ng/ml/hour, normal in adults, is not reached until about the age of six.[37,38] Higher renal vascular resistance in children under 6 years could be due to higher values of PRA in this age group; however, additional research should be conducted to prove eventual relation between PRA and Doppler resistance index.

Doppler ultrasonography plays an important role in the non-invasive diagnosis of renal artery stenosis.[18-20] Two important signs detectable by Doppler are: (1) high velocity at the site of stenosis in the main renal artery and (2) in high-degree stenosis "parvus and tardus" spectra in the intrarenal arteries, mainly characterized by increased acceleration time (AT). The latter sign is especially important in children in whom renal artery stenosis due to the fibromuscular dysplasia is much more common than in adults in whom renal artery stenosis (RAS) is most commonly

caused by the ostial atherosclerotic disease. The significance of the AT measurement in the intrarenal arteries and detection of "parvus and tardus" spectra in the diagnosis of renal artery stenosis was first described by Stavros in 1992[21] and, only since, this parameter has been measured in adults. No investigation of AT in healthy children could be found in the literature. We have therefore studied the acceleration time values in healthy children. AT was not measured in adult population in a larger group of examinees. But it was observed that the values are very low, and some authors consider the values below 0.10 sec. as normal AT values in adults. Apparently, there is no difference between children and adults in the systolic portion of intrarenal arterial spectra and, consequently, also in AT values. So, the AT values in children and in adults can be interpreted in the same way.

ATs were very low, with low variability of measured values, and no differences observed between age groups of children, as well as in comparison to adults. Thus, renal artery stenosis in childhood can be diagnosed on the basis of the same criteria as in adults.

Doppler studies are very dependent on the experience of the examiner, technical quality of the US scanner and optimal examination technique (arteries in which RIs are measured, number of measurements, automatic or manual calculation). It is very important to insonate as many intrarenal arteries as possible, to adjust the optimal pulse repetition frequency and wall filter and to have enough time on disposal to perform the study optimally. All these requirements are even more important in children who are often not cooperative enough during the examination.

There are only four prior reports of normal renal RI values with larger number of children, published between 1992 and 1997.[31,34] If data from these reports are converted to the mean renal RI of the similar age groups like in this study, the values of resistance index in the youngest age group (2-6 years) are significantly higher in our study (RI=0,70) compared to the studies of Lin *et al.* (mean RI=0,65)[32] and Bude *et al.* (mean RI=0,64),[33] but very similar to results of Scholbach *et al.* (RI=0,71)[31] and Vade *et al.* (RI=0,69).[34] In the age group II (>6-11 years), RI is similar in all studies (RI=0,62), except in Scholbach's[31] who reported higher values (RI=0,70). In the third age group (>11-16 years), the values of RI are equal to those reported by Vade *et al.* (RI=0,58) (34), similar to Bude's (RI=0,59)[33] and Lin's (RI=0,62),[32] and cannot be compared to the results of Scholbach *et al.*[31] where children over 6 years are not divided into further age subgroups.

The comparison of our results to the studies of Scholbach *et al.*,[31] Bude *et al.*[33] and Lin *et al.*[32] is not precise due to older, technically inferior types of Doppler US scanners used in those studies. This is especially applicable to the study of Bude[33], who calculated manually from scans using micrometer on the old type of US scanner. Scholbach measured RI values only once, in main renal arteries where the values are known to be higher compared to intrarenal arteries.[31] He divided the children under 6 years into 3 age subgroups and found equal values of RI in all of these subgroups, significantly higher compared to older children. The values of RI in this study are about 5% higher then ours. Lin measured RI in segmental arteries without specifying the number of measurements.[32] The studies in adult population showed that the resistance index at the level of the interlobar-arcuate arteries is the most constant Doppler parameter and should be preferred in clinical applications.[39] Our data for children 2-16 years old are in agreement with Vade's, published in 1993; which comprised 95 children from 0 to 18 years and conducted measurement on the same state-of-art Acuson 128 XP scanner.[34] The measurements of RI were obtained also from interlobar arteries and calculated as an average of three values from different parts of

the kidney as in our study. The number of children in the same age range in this study is 150, and in Vade's report 56. Vade did not measure AT.

In conclusion, we were able to obtain an adequate Doppler sonogram and measure RI and AT in intrarenal arteries by color duplex Doppler ultrasonography in all examined children. It has been demonstrated that the Doppler index of resistance in early childhood is considerably higher as compared to the adult population; however, after the 6 years, all RI values are below 0,70. Therefore, the utilization of the 0.70 RI as a threshold value for the increased vascular resistance in adults can be also applied to children over 6 years. In younger children, the RI values should be interpreted on the basis of normal values in a particular age group. The acceleration time values in children are not different as compared to adults. The detection of renal artery stenosis on the basis of analysis of intrarenal Doppler arterial systolic spectral morphology and measurement of AT are the same in children and in adults.

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