Doppler Sonography in the Detection of Significant Renal Artery Stenosis

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Background

Systemic hypertension is a major risk factor both for stroke and for myocardial infarction. The search for underlying treatable cause is a part of the management of a hypertensive patient. Renal vascular hypertension is the most common form of potentially curable hypertension and if untreated may terminate in renal failure. It has been estimated that 10% to 20% of new patients presenting with end-stage renal disease have treatable renal vascular disease. The purpose of screening strategies is to identify significant renal artery stenosis (RAS) in earlier stages before irreversible damage or loss of renal mass occurs. Due to the relatively low prevalence of RAS in the hypertensive population an inexpensive, accurate and non-invasive screening test is required in patients with normal or impaired renal function. Duplex Doppler sonography (DUS) is non-invasive screening test for the detection of RAS. It combines visualization of renal arteries with measurement of various hemodynamic factors within the kidney. Recent studies have shown improvement of diagnostic values of DUS. Encouraging results were obtained by the combination of extrarenal and intrarenal Doppler scanning (2,3,4,5).

The aim of the study was to determine the usefulness of DUS of the renal arteries in identifying patients with RAS >50%.

Subjects and methods

We prospectively analyzed 41 patients, 18 women and 23 men, aged from 16 to 66 years (mean age 39.9±13.1) during the period 1997-2002 for possible renal artery stenosis. All studied patients had difficult to control hypertension or unexplained azotemia, making them highly suspicious for renovascular disease. Thirteen of forty-one patients (32%) had serum creatinin>120μmol/l, including one patient on dialysis. A smaller number of patients were evaluated because of associated cerebrovascular disease, and coronary artery disease. (Table1).

All patients were examined by conventional sonography, color Doppler and pulsed Doppler sonography with Esaote Au4 Idea using 3.5 MHz curved array transducer with 2.5 MHz pulsed Doppler. Doppler sonography was first examination in 34 patients (82.9%).No pre-investigation fasting period was required. If excess bowel gas was present, the patients were studied the following morning before breakfast. Patients were studied in anterior and lateral decubitus position. The kidney size was measured at its longest axis. The renal arteries were first visualized in their longitudinal plane and spectral waveforms were obtained from proximal and medial portions of the renal artery. The Doppler angle was chosen as smallest possible and less than 60º. Criterion for feasibility was the visualization of the entire course of at least one renal artery on each side. The peak systolic velocity (Vp) is a measure of a maximum velocity of blood flow during systole. The renal-aortic ratio was calculated by dividing the Vp in the renal artery by the Vp in the aorta. If an aliasing and turbulence phenomenon could be observed, a pulsed Doppler was obtained from the region of maximum aliasing. At least three measurements in the deferent interlobar arteries, covering the upper pole, the midportion and the lower pole of each kidney were registrated and an average value - mean resistive index (RI) was calculated. RI was calculated according to the formula: RI = (peak systolic velocity minus minimum diastolic velocity) divide by peak systolic velocity. The differences between mean RIs of both kidneys delta RI (Δ RI) were estimated for each participant.

RAS of 50% or more was diagnosed if the Vp in any part of the main renal artery was 180 cm/sec or more and renal aortic ratio was 3.5 or more (5,9). If no adequate Doppler signals from renal artery the diagnosis depended on ΔRI of interlobar arteries exceeding 0.05. Renal artery stenosis was suspected on the site with the lower RI (4,8). Occlusion of the renal artery was diagnosed by the absence of a flow signal in the renal artery and by low-amplitude parenchyma signal.

Angiography was used as a "gold standard" in the diagnosis of RAS in 40 patients. Magnetic resonance angiography with gadolinium enhancement was performed in one woman with thrombopenia. Indication of angiography were DUS findings suggesting a stenosis (n 21), a high suspicion for the presence of RAS despite normal findings in DUS and the need to definitively exclude RAS (n 20). Renal angiography was carried out by means of intra-arterial digital subtraction angiography with conventional Seldinger technique via a transfemoral approach. Criterion for the diagnosis RAS was a luminal narrowing of 50% in diameter or more. The contrast media used was non-ionic, low-osmolar iodized (Ultravist 300, Ultravist 370, Schering, Berlin and Omnipague 350, Nycomed, Amersham). The results of DUS were compared with the findings on angiography.

Statistical methods

Results are expressed as means±SD values and per cent. Student's t-test for unpaired observation were used. Statistical significance was defined as $p<0.05$. Sensitivity, specific-

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ity and predictive values were determined using the four-fold table.

Results

A total of 41 patients with arterial hypertension were examined in the study. Clinical data of the patients are presented on table 1.We studied 81 arteries in 80 kidneys. Only one patient had accessory renal artery on angiography, which was a smaller number than we expected. Renal artery stenosis >50% according to angiography was found in 19 patients giving a prevalence of 46%. Twenty-one arteries were narrowed: two arteries had stenosis>50%, sixteen arteries had stenosis >70% and three arteries were with total occlusion. Two patients had bilateral RAS. All stenosis affected main renal artery.Ten patients had fibromuscular dysplasia and nine patients had atherosclerosis of the renal arteries. Twenty two from 41(54%) patients had no RAS.

Table 1. Clinical patients' data

	No stenosis	RAS
Patients number	22	19
Age in years	42.6±12.8	37.3±13
Women/Men	6/16	12/7
Serum creatinin>120μmol/l n(%)	6 (27%)	7 (36.8%)
Serum potassium<3.5mmol/l n(%)	1 (4.5%)	1 (5%)
Dyslipidemia n(%)	10 (45%)	6 (31.5%)
Body mass index kg/m² range	20-30	19-28
Diastolic blood pressure>120mm Hg n(%)	11 (50%)	8 (42%)
Patients with 3 or more antihypertensive drugs n(%)	10 (45%)	8 (42%)
Difference of kidney sizes >15mm n(%)	4 (20%)**	11 (57.8)*
Cerebral vascular disease n(%)	1 (4.5%)	3 (15%)
Coronary artery disease n(%)	4 (20%)	0
Diabetes mellitus n(%)	1 (4.5%)	3 (15%)
Abdominal bruit n(%)	0	5 (26%)
Smoking n(%)	13 (59%)	10 (52.6%)

* One patient had renal hypoplasia of the left kidney and RAS of the right renal artery.

** Two patients had only one kidney and they were excluded.

Kidney size difference did not help to distinguish hypertension due to RAS from essential hypertension. A kidney length less than 85mm was associated with an occluded renal artery. Seventy two arteries were visualized of the entire course including one accessory artery by DUS. Six main renal arteries were not adequately visualized. Three of those arteries were angiographycally normal and three were narrowed >70% and in only two of them there were indirect signs of significant stenosis (ΔRI>0.05). Direct visualization of main renal arteries was possible in 37 patients (92%). Three arteries with total occlusion of the renal artery on angiography showed total occlusion on DUS. Peak systolic velocities were from 80 to 120 cm/sec in the arteries without stenosis except three arteries (220 cm/sec) and from 180 to 290 cm/sec in the area of aliasing in the stenotic arteries.

The mean renal aortic ratio in the stenotic arteries was higher - 4.8±1.1 than mean renal aortic ratio in the arteries without stenosis - 2.7±1($p<0.001$). The mean RI of stenotic kidneys was 0.46±0.09 (from0.36 to 0.62) and the mean RI of kidneys without RAS was 0.58±0.05 (from 0.50 to 0.69). The values of RI were depended of age and renal function. The higher was ΔRI in group with RAS 0.09±0.05 (from 0.03 to 0.20) compared to theΔRI in group without RAS 1.9±1.3 (from 0 to 0.04) ($p<0.001$). The ΔRIs were <0.04 in three cases with ostial stenosis. The ΔRI could not be used in two patients with single kidney and in two patients with bilateral stenosis. Doppler sonography identified RAS in 20 arteries, 3 occluded arteries (3 false positive) and 58 arteries without stenosis (1 false negative). The sensitivity of DUS was 95.2%, the specificity was 95%, the positive predictive value was 86.9% and the negative predictive value was 98.2% (table2).

Table 2. Angiography and Doppler sonography test results in 41 patients

Aortography	Doppler sonography Negative	Positive	Total
No RAS	57	3	60
RAS	1	20	21
Total	58	23	81

Discussion

The main renal artery was successfully visualized in 90% of the patients. The false negative result was explained with the place of stenosis, it was ostial stenosis. All three false positives had both aliasing and turbulence on Color Doppler and Vp>180cm/sec and RAR>3.5. Different threshold values of peak systolic velocities have been used to establish diagnosis of renal artery stenosis from 140 to 220 cm/sec. The most acceptable cut off is 180cm/sec. The ΔRIs were not usful in three cases with ostial stenosis, in patients with single kidney and bilateral RAS. Duplex Doppler sonography correlated well with angiography. In the current study diagnostic value of DUS were higher than 90% and was comparable with reported values of other imaging modalities (7). Using the same diagnostic criteria our results were similar to those published by B. Krumme and J. Riehl. The ways to improve the accuracy of DUS are use of echocontrast media (2), use of captopril prior to investigating the patient by DUS. Future generation of ultrasound machines will probably facilitate the detection of RAS.

Detection of RAS is important since it is a potentially curable cause of hypertension, by means of percutaneous transluminal angioplasty, stenting, or surgical revascularization (1). Conventional x-ray angiography provides definitive

anatomic confirmation of stenosis but is an invasive, expensive and is not suitable as a screening method. A noninvasive test is a very desirable alternative. Captopril enhanced renal scintigraphy is a test with good sensitivity and specificity, but does not perform equally well in patients with diminished renal function. Magnetic resonance angiography is a very promising modality in this field, it is non-invasive but expensive. Contrast enhanced helical CT is a promising test also. The need of iodinated contrast medium, however, does not allow its widespread use as a screening test. Duplex Doppler ultrasonography has definite advantages over captopril scintigraphy, Magnetic resonance and spiral CT for the evaluation of renal artery disease (9). Direct visualization of arterial lesions, lack of ionizing radiation or contrast injection and reduced cost favor ultrasound as the initial examination for the evaluation of RAS.

We conclude that Duplex Doppler sonography, evaluating both main renal and intrarenal arteries, is an ideal screening test because it is noninvasive, cost effective, and can predict the presence or absence of RAS with a high degree of accuracy, irrespective of renal function.

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