Klinische Wochenschrift

Organ der Gesellschaft Deutscher Naturforscher und Ärzte

Springer-Verlag Berlin Heidelberg New York London Paris Tokyo Hong Kong Barcelona

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Autorenregister

Die halbfetten Zahlen bezeichnen Originalarbeiten, die Zahlen in gewöhnlicher Schrift Buchbesprechungen

Redaktion: Springer-Verlag München, Agnes-Bernauer-Platz 8, W-8000 München 21
Schriftleitung: Prof. Dr. N. Zöllner, Medizinische Poliklinik der Universität München, Pettenkoferstr. 8a, W-8000 München 2
Anzeigen: E. Lückermann, C. Hänzi, Springer-Verlag, Heidelberger Platz 3, 1000 Berlin 33
Druckerei: Universitätsdruckerei H. Stürtz AG, Beethovenstr. 5, W-8700 Würzburg

Springer Verlag GmbH & Co. KG, 1000 Berlin 33

Klin Wochenschr (1990) 68:830–834

Klinische Wochenschrift

Duplexsonography in the Diagnosis* of Renovascular Hypertension

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Summary. Duplexsonography (DS) has become a well established method for diagnosing peripheral vascular diseases. Technical developments (higher resolution of transducer and deeper penetration) have made also abdominal and retroperitoneal vessels, including renal arteries, accessible for duplexsonography. This method provides the opportunity to recognize renal artery stenoses causing renovascular hypertension without invasive procedures. We therefore examined 86 hypertensive patients with a high likelihood of renovascular hypertension. Due to technical problems (bowel gas, adipositas) we excluded 7 patients. 79 patients (17–79 years) were included in our study. Flow patterns of several renal vascular areas were evaluated while the renal artery was demonstrated on a B-scan. A spectrumanalysis included the evaluation of the frequency pattern (widening of the frequency band and loss of a frequency free window below the systolic rise?), the sloping of the diastolic shoulder, and the calculation of different parameters like accelerationindex, decelerationindex, resistanceindex, accelerationtime, and systolic peak velocity. The accuracy of DS in diagnosing renal artery stenoses was compared with arterial digital substraction angiography (DSA).

Renal artery stenoses was diagnosed in 21 out of 158 renal arteries (13%). Except for the systolic peak velocity no significant correlations could be found of any of the indices from spectrumanalysis with hemodynamically significant stenoses (>50%). However, the following 3 criteria proved to be valuable signs of a hemodynamically significant stenoses: 1) Maximal systolic accelaration >3 m/s, 2) Steep sloping diastolic shoulder, and 3) Turbulence of all frequency ranges without a frequency free window below the systolic rise.

Compared with DSA the sensitivity of DS was 84,0%, the specificity was 98,5%, and the predictive value 91% in significant stenoses. Abdominal DS seems to be a potent noninvasive method in diagnosing renal artery stenoses with a good sensitivity and a high specifity and a high predictive value.

Key words: Duplexsonography – Renal artery stenosis – Hypertension – DSA

Hypertension caused by renal artery stenoses is the most common form of secondary hypertension [2]. Since the diagnosis of renovascular hypertension has important clinical implications with regard to surgery and angioplasty treatment or medical therapy, an easy accesible noninvasive diagnostic test is desirable. The technical progress in combining conventional ultrasonography and Doppler echo (duplexsonography) has enabled the assessment of blood flow spectrumanalysis in renal arteries. We therefore initiated a prospective study to evaluate sensitivity and specifity of duplexsonography (DS) as compared with DSA. Furthermore the value of different Doppler parameters like accelarationindex, decelerationindex, resistanceindex, accelerationtime, and systolic peak velocity should be tested.

Methods

Patients. From May 1988 to October 1989 all hypertensive patients of the Medizinische Poliklinik with signs of secondary hypertension, e.g. severe hypertension, high diastolic blood pressure, accel-

* Herrn Prof. Dr. med. W. Seitz zum 85. Geburtstag gewidmet

Abbrevations: DSA = arterial Digital substraction angiography

Fig. 1. Illustration of the right kidney (cross section) and the right renal artery on B-scan with positioning of the Doppler sample volume in the renal artery (white dot)

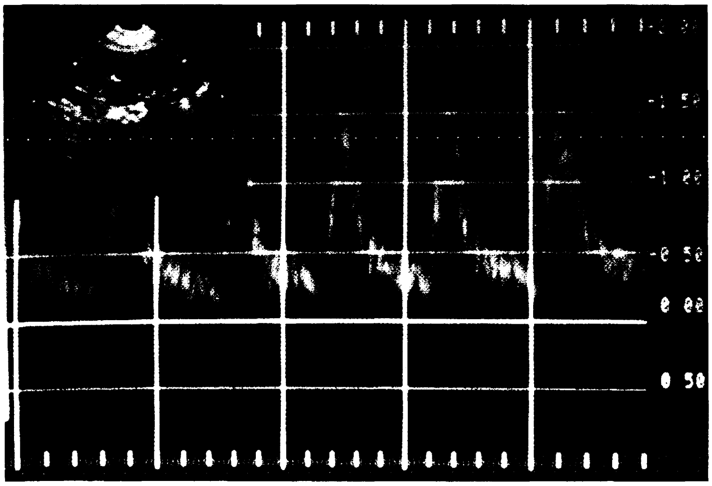

Fig. 2. Spectrumanalysis of a renal artery showing a normal flow pattern with a steep and high systolic rise, a steeply sloping diastolic shoulder with a frequency free window, and a systolic peak velocity of 1,6 m/s

eration of hypertension during the previous 6 months, end organ damage like retinopathy III and IV and left ventricular hypertrophy, and abdominal bruits were examined. After a complete physical examination the protocol included several blood pressure measurements including 24 h registration, a routine blood test, a regular ultrasound of the abdomen and DS of the renal arteries. All patients were then referred to the radiology department for arterial DSA. All investigations were evaluated independently.

Sonography. Complete ultrasonography of the abdomen including the determination of the kidney sizes was done. DS was performed by an experienced investigator from ventral with the patient lying on the side using a 3.0 MHz transducer (Ultramark 5, ATL). Real-time-B-Scan were used to identify the renal arteries and to display them on the screen during duplexscanning (Fig. 1). Successful display was given in all 79 patients. The doppler sample volume was focused on an area in the artery at an angle of 40 to 70 degrees. The flow signals received from this area were used for spectrumanalysis (Fig. 2). The doppler frequency signal and spectrum was displayed graphically against time. The spectrum is either expressed in kiloherz corresponding to the frequency variation caused by the Doppler effect or in m/s converted to flow velocity and corrected for the used angle (Fig. 3). Accelerationindex (m/s^2), decelerationindex (m/s^2), resistanceindex and accelerationtime (s) were calculated. The accelerationindex is defined as maximal systolic frequency minus enddiastolic frequency divided by the maximal systolic frequency. The decelerationindex is computed as difference of the maximal systolic frequency minus enddiastolic frequency divided by the acceleration time. The acceleration time is taken from the onset of the systolic rise to the point of the systolic peak.

The results from DS were to be categorized into four groups:

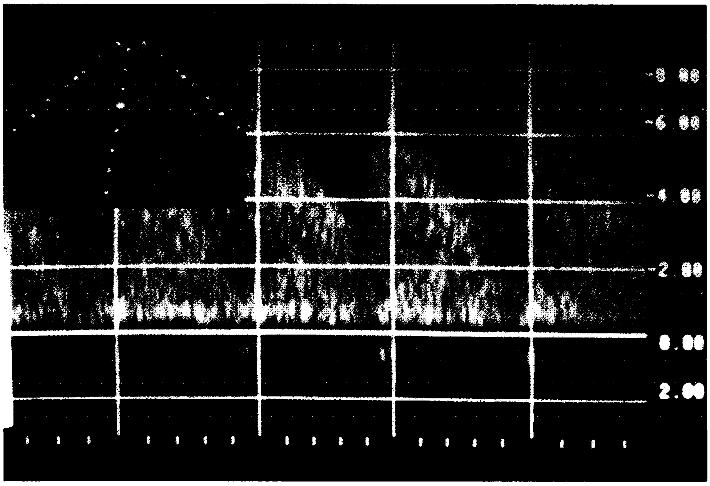

Fig. 3. Spectrumanalysis of a significant renal artery stenosis with turbulences in all frequency ranges, without a systolic window, with a sloping diastolic shoulder, and a maximal flow velocity of 8,5 m/s

1) normal renal artery, 2) non significant stenoses (< 50%), 3) hemodynamically significant stenoses (> 50%), and 4) occlusion.

To differentiate between hemodynamically significant and non significant stenoses we used the criteria derived from a pilot study [11] and from experiences made with DS of the A. carotis [10]. Significant arterial stenoses is characterized by an increased peak velocity, a steep sloping of the diastolic shoulder since the flow never reaches zero and never drops below 50% of the systolic peak, and a turbulant blood flow leading to a broader frequency band and resulting in the loss of the systolic window.

Digital substraction angiography. Arterial DSA was performed without knowing the results of DS. The morphologic results derived from DSA were categorized into the same 4 groups as with DS.

Statistics

For the calculations of the indices from spectrumanalysis we used the student-*t*-test. Sensitivity, specificity and predictive value (post test probability) were calculated using the four fold table.

Results

During May 1988 to October 1989 we examined 158 renal arteries from 79 patients (49 male and 30 female) with a mean age of 49.5 years (17–79). Comparison of DS with DSA showed the following results (Table 1): Out of 158 arteries 131 were normal and 21 had a hemodynamically significant stenoses both with DS as well as with DSA, 2 were classified as hemodynamically significant stenoses by DS but were normal on DSA, and 4 were classified as normal by DS but were hemodynamically stenosed on DSA. Thus the sensitivity was 84,0% and the specificity was 98,5%. The two cases of false positive diagnosis in DS were in patients with right sided renal atrophy.

Table 1. Comparison of duplexsonography (DS) with arterial digital angiography (DSA) in hemodynamically significant renal artery stenoses

	DSA path.	DSA normal	∑
Duplex path.	21	2	23
Duplex normal	4	131	135
∑	25	133	158

Sensitivity: 84,0%
Specificity: 98.5%
Predictive value: 91%

The four cases of false negative diagnosis were all in patients with renal artery stenoses in the left kidney. No renal artery occlusion was diagnosed with either method.

7 renal arteries showed fine and pearly changes indicating fibromuscular dysplasia. All other stenoses were of arteriosclerotic origin. None of the parameters from spectrumanalysis (accelerationindex, decelerationindex, resistanceindex and accelerationtime) were significantly correlated with significant stenoses on DSA (Table 2). Only a systolic peak velocity above 3 m/s, an absence of a window below the systolic rise and a widening of the spectrum with a sloping diastolic shoulder revealed to

Table 2. Results ($\bar{x} \pm SD$) of the calculated indices from spectrumanalysis in normal renal arteries (A) and in significant renal artery stenoses (B)

Accelerationindex (m/s^2)		
Group A ($n=131$)	$\bar{x}=19.55 \pm 13.32$	
Group B ($n=23$)	$\bar{x}=20.69 \pm 19.52$	n.s.
Decelerationindex (m/s^2)		
Group A ($n=131$)	$\bar{x}=2.97 \pm 3.48$	
Group B ($n=23$)	$\bar{x}=3.48 \pm 3.95$	n.s.
Resistanceindex		
Group A ($n=131$)	$\bar{x}=0.66 \pm 0.08$	
Group B ($n=23$)	$\bar{x}=0.61 \pm 0.22$	n.s.
Accelerationtime (s)		
Group A ($n=131$)	$\bar{x}=0.07 \pm 0.03$	
Group B ($n=23$)	$\bar{x}=0.11 \pm 0.06$	n.s.

be diagnostic criterias indicating a renal artery stenoses by duplexsonography.

Discussion

Our results show that duplexsonography has a good sensitivity, a high specificity and a high predictive value in diagnosing renal artery stenoses which is consistent with earlier results derived from smaller samples [1, 3, 6, 8, 9, 11]. The sensitivity of the method is limited by problems with the left kidney due to anatomical (overlying bowel loop) or functional (meteorism) conditions influencing the recognition of the renal artery over the full length. A stenoses very close to the origin of the left renal artery can be overlooked when this area can not demonstrated on B-scan. If in this case the Doppler sample volume is placed in the area of the post-stenotic dilatation the derived flow pattern is considered to be normal. In fact the evaluation of the proximal left renal artery has often to be done blindly, e.g. that the sample volume is placed in the hilus without recognizing the left renal artery.

Earlier studies reported on correlations between hemodynamically significant stenoses and various frequeny patterns [1, 3, 4, 8, 9]. However, we found no significant correlations between these different indices calculated from spectrumanalysis and hemodynamically significant stenoses.

A systolic peak flow velocity of >1 m/s or $>1,4$ m/s was reported to be a sign of hemodynamically significant stenoses [3, 9]. However, in 51 normal renal arteries (26 rightsided and 25 leftsided) we found a flow of $>1,4$ m/s (maximum 2,7 m/s). This parameter alone appears to be invalid for diagnosing renal artery stenoses. Based on the results from this study we suggest the following criteria to diagnose renal artery stenoses:

1) Systolic peak velocity >3 m/s

2) Widening of the frequency spectrum with a steep sloping of the diastolic shoulder

3) Absence of a window below the systolic peak.

Duplexsonography appears to be a highly sensitive method for diagnosing hemodynamically significant renal artery stenoses with the exception for leftsided proximal stenoses. DS should be considered as one of the new noninvasive diagnostic steps in renovascular hypertension comparable with ambulatory 24-h blood pressure measuring [5, 7]. However, a normal DS result does not exclude renovascular hypertension and arterial DSA or direct renal angiography has to be performed in suspicious cases. Using **venous** DSA vascular details especially in the periphery can not be detected; therefore it is considered to be inappropriate in the stepped diagnosis of renovascular hypertension.

Whether a normal DS and a normal 24-h blood pressure profile can exclude hemodynamically significant renal artery stenoses and render invasive angiography unnecessary has to be answered in future studies.

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Eingegangen: 19. März 1990
Zurück zur Überarbeitung: 9. Mai 1990
Angenommen: 21. Juni 1990

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