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PRACA ORYGINALNA

The effect of successful renal artery correction on intra-renal Doppler flow parameters in hypertensive patients with renal artery stenosis

Wpływ skutecznego zabiegu poszerzenia światła tętnicy nerkowej na parametry przepływu wewnątrznerkowego oceniane w badaniu dopplerowskim u chorych z nadciśnieniem tętniczym i zwężeniem tętnicy nerkowej

Streszczenie

Wstęp Celem prezentowanego, prospektywnego badania była ocena wpływu skutecznego zabiegu poszerzenia światła tętnicy nerkowej (za pomocą angioplastyki lub chirurgicznego) na parametry przepływu wewnątrznerkowego oceniane w badaniu dopplerowskim tętnic nerkowych u chorych z nadciśnieniem tętniczym, zwężeniem tętnicy nerkowej i prawidłową funkcją nerek.

Materiał i metody Do badania włączono 30 chorych z nadciśnieniem tętniczym (średnia wieku 53,3 ± 2,0 lat; zakres 33–75 lat; 18 M, 12 K) i z angiograficznie potwierdzonym miażdżycowym zwężeniem tętnicy nerkowej. Badanie dopplerowskie tętnic nerkowych wykonywano przed (0) i tydzień (I), 6 miesięcy (II) i rok (III) po skutecznej korekcji zwężenia tętnicy nerkowej. Na podstawie analizy widma przepływu wyliczano: maksymalną prędkość skurczową (Vmax), przyspieszenie narastania fali skurczowej (Acc), czas przyspieszenia (AcT), indeks pulsacji (PI) i indeks oporowy (RI). Całodobowe monitorowanie ciśnienia tętniczego wykonywano przed korekcją zwężenia tętnicy nerkowej i rok po (III) niej. Pacjentów podzielono na dwie grupy w zależności od efektu zabiegu ocenianego po roku: grupę 1 (wyleczoną) — chorzy, u których nie stosowano leczenia hipotensyjnego, ze średnim ciśnieniem tętniczym z ciągu doby wynoszącym poniżej 135/85 mm Hg oraz grupę 2 (niewyleczoną) — chorzy otrzymujący nadal leczenie hipotensyjne.

Wyniki W całej grupie łącznie, grupie 1 i grupie 2 obserwowano obniżenie Vmax w badaniach I, II i III w porównaniu z 0. Przyspieszenie było obniżone przed korekcją zwężenia tętnicy nerkowej, następnie obserwowano istotny wzrost Acc w badaniach I, II i III w porównaniu z 0 w całej grupie łącznie, grupie 1 i grupie 2. Czas przyspieszenia był wydłużony przed korekcją zwężenia tętnicy nerkowej, istotne obniżenie AcT w porównaniu z wartościami wyjściowymi obserwowano w badaniach I, II i III w grupie 2 i całej grupie. W grupie 1 nie obserwowano różnic między wartością RI w badaniach I, II i III w porównaniu z wartościami wyjściowymi (odpowiednio: 0,54 ± 0,02, 0,56 ± 0,03, 0,55 ± 0,04 *vs.* 0,52 ± 0,04; p = NS). W grupie 2 średnia wartość RI wzrosła nieistotnie w badaniach I, II i III w porównaniu z 0 (odpowiednio: 0,64 ± ± 0,02, 0,94 ± 0,05, 0,63 ± 0,02 *vs.* 0,61 ± 0,02 p = NS). Średnie wartości RI były istotnie wyższe w grupie 2 w porównaniu z grupą 1 w badaniach 0 i I. Obserwowano istotnie statystycznie niższe wartości PI w grupie 1 w porównaniu z grupą 2 w badaniach 0 i I.

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Wnioski Uzyskane wyniki wskazują na brak wpływu skutecznej korekcji zwężenia tętnicy nerkowej u chorych z nadciśnieniem tętniczym i prawidłową funkcją nerek na indeks oporowości i pulsacji. Ocena przyspieszenia i czasu przyspieszenia ma znaczenie w obserwacji chorych po korekcji zwężenia tętnicy nerkowej pozwalając na ocenę skuteczności leczenia.

słowa kluczowe: zwężenie tętnicy nerkowej, angioplastyka, leczenie chirurgiczne, badanie dopplerowskie tętnic nerkowych, parametry wewnątrznerkowe

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Introduction

Doppler ultrasonography has received considerable attention for the diagnosis and depiction of renal artery stenosis (RAS) and has enabled the main and segmental renal arteries to be examined. Duplex ultrasonography can provide images of the renal arteries and assess blood-flow velocity and pressure waveforms [1, 2].

In recent years several intra-renal Doppler waveform parameters have been evaluated for detecting RAS, including systolic acceleration and acceleration time. Some reports have also investigated, with encouraging results, the efficacy of intra-renal resistance parameters [3, 4].

However, few studies have used Doppler ultrasonography to follow up patients after renal artery revascularisation on the basis of assessment of intra and extra-renal scanning. It should also be noted that the patients included in the studies varied with regard to age and renal function [5, 6].

Therefore the aim of this prospective study was to evaluate the effect of successful renal artery correction (angioplasty or surgery) on intra-renal Doppler flow parameters in hypertensive patients with RAS and preserved renal function.

Material and methods

Since 1996 colour Doppler ultrasonography has been performed on 5,450 hypertensive patients in the 2nd Department of Clinical Radiology, providing identification of renal artery stenosis with a sensitivity of 85% and specificity of 94% [7].

The study included 30 hypertensive patients (mean age: 53.5 ± 2.0 yrs, age range: 33–75 years; 18 males, 12 females) with clinical features suggestive of renal artery stenosis and arteriographically confirmed RAS. All subjects had renal artery stenosis with a reduction in diameter exceeding 60% as documented by arteriography.

This study protocol was approved by the Ethics Committee and all patients provided written consent.

The aetiology of the arterial lesions was atherosclerotic in all 30 cases (non-ostial lesions in most cases) according to arteriographic criteria. Most of the patients (83%) were taking antihypertensive drugs, including beta blockers, diuretics, alpha blockers and angiotensin-converting enzyme inhibitors (the latter used only in patients with unilateral RAS).

In 25 patients successful angioplasty was performed (followed by stent placement in 3 cases with ostial stenosis), 5 were surgically treated. Angioplasty was performed using a ballon catheter (PowerFlex, Cordis-Johnson and Johnson) equal to the diameter of the renal artery. After dilatation post-angioplasty angiography was performed to assess the technical outcome. Where there was residual stenosis of more than 15% diameter reduction, additional dilatation was performed and the outcome was verified by intra-arterial pressure measurement. The operative techniques usually included the placement of an aortorenal vein or synthetic graft.

Since the main goal of our study was to evaluate whether intra-renal Doppler flow parameters can be used prospectively to predict the clinical outcome after revascularisation, we decided to include only those patients (30 selected from the total number of 65 patients) with no Doppler duplex or angiography signs of re-stenosis detected over 1 year of observation and those with normal renal function and successful measurement of all velocimetric indices.

Intra-renal Doppler flow parameters were evaluated before (0) and during a one-year follow-up period after successful renal artery correction (angioplasty or surgery) in hypertensive patients with RAS. To ascertain this, the Doppler duplex ultrasonographic procedure was repeated at 1 week (I), 6 months (II) and 12 months (III) post-interventionally. Repeated renal arteriography was performed in cases where the ultrasonographic criteria (RAR > 3.5) suggested re-stenosis or stenosis at a new site.

The Doppler duplex sonographic examination was performed using a ATL 3000 HDI device with a 2–4 MHz convex transducer. Each examination included evaluation of renal artery flow, which was measured along the trunk at the highest value of peak systolic velocity recorded. For the artery trunk evaluation the transverse midline approach was applied in most patients, with intercostal scanning in larger persons. All the examinations were performed by two experienced sonographers [7].

For the artery trunk Doppler measurements consisted of maximum flow velocity (Vmax) and for the

assessment of stenosis the renal-aortic ratio (RAR) was calculated by dividing the Vmax (renal artery trunk) by the maximum flow velocity in the aorta, which was then expressed as an absolute number.

Intra-renal Doppler signals were obtained from segmental branches of the upper and lower parts of the kidney because a clear signal can always be obtained from these arteries. A clear signal is needed for the measurement of the resistive index to be reliable. Analysis of the Doppler spectra was performed with the apparatus software in order to derive the following parameters: maximum systolic velocity (Vmax), minimum diastolic velocity (Vmin) (end-diastolic velocity Vmin), mean velocity (Vmean) and the time to peak systolic velocity (t). From these parameters the following indices were calculated:

— Pulsatility index = Vmax – Vmin/Vmean,
— Resistive index = Vmax – Vmin/Vmax,
— Acceleration = $Vmax/t^2$ (m/s^2),
— Acceleration time = t (ms).

24-hour blood pressure monitoring was performed before and 12 months (at III) after RAS correction with Space Labs 90207 monitor (Redmond, Washington, USA).

Readings were obtained every 15 min during the day (6:00–23:00) and every 20 min during the night (23:00–6:00). Serum creatinine concentration was determined by standard methods.

The patients were classified into two groups, those cured (Group 1) and those not cured (Group 2), according to the clinical outcome after successful renal artery stenosis correction. In the first group antihypertensive treatment was discontinued permanently and 24 h BP was < 135/85 mm Hg following PTRA or surgery without antihypertensive medication. In the second group antihypertensive treatment was maintained or modified but not discontinued.

For a comparison of means and parameter changes in the basal and follow-up groups, the t-test was employed for independent and dependent samples respectively. The results throughout are presented as mean ± standard error of mean (SEM). $P < 0.05$ was considered statistically significant.

Results

Of 30 patients with RAS, the stenosis was corrected with angioplasty in 25 cases (with a stent in 3 cases) and surgically in 5 patients.

The changes in 24-hour blood pressure after successful correction were therefore evaluated. Group 1 was made up of 8 patients and Group 2 consisted of 22 subjects. In the latter group adequate control of blood pressure was maintained in 8 patients on the same number of antihypertensive drugs as compared to pre-interventional period, in 7 the number was decreased and in a further 7 the number of drugs was increased. Table I shows the characteristics of the group studied.

It should be noted that ultrasound scanning of the renal arteries and measurements of the velometric indices during the one-year follow-up period were technically successful in all patients.

Renal artery trunk

In both Group 1 and Group 2, taken as a whole, a statistically significant decrease in Vmax was observed at I, II and III as compared to the pre-intervention period (Table II), proving the success of the renal artery correction. Groups 1 and 2 did not differ in terms of Vmax on any of the four occasions.

Table I. Characteristics of patients — baseline (0) and 12 months after correction (III)
Tabela I. Charakterystyka chorych — przed (0) i 12 miesięcy po zabiegu (III)

	Whole group	Not cured	Cured	p*
Age (years)	53.5 ± 2.0	55.3 ± 2.2	48.5 ± 4.1	NS
Number of antihypertensive agents at 0	2.0 ± 0.2	2.1 ± 0.3	1.6 ± 0.6	NS
Number of antihypertensive agents at III	1.6 ± 0.3	2.2 ± 0.3	0	< 0.001
24 h systolic BP at 0 [mm Hg]	149 ± 3	152 ± 3	142 ± 7	NS
24 h diastolic BP at 0 [mm Hg]	90 ± 2	89 ± 2	91 ± 4	NS
24 h systolic BP at III [mm Hg]	129 ± 3	133 ± 3	120 ± 3	< 0.05
24 h diastolic BP at III [mm Hg]	79 ± 1	80 ± 2	78 ± 2	NS
Creatinine at 0 [mg/dl]	1.18 ± 0.07	1.22 ± 0.10	1.09 ± 0.22	NS
Creatinine at III [mg/dl]	1.12 ± 0.06	1.13 ± 0.07	1.10 ± 0.08	NS

BP, blood pressure. Data are given as mean ± SEM. *Statistical significance between the group cured and the group not cured

Table II. V max, RAR, AcT and Acc before (0) and 6 weeks (I), 6 months (II), 12 months (III) after the correction

Tabela II. Vmax, RAR, AcT i Acc przed (0) i 6 tygodni (I), 6 miesięcy (II), 12 miesięcy (III) po zabiegu

		V max [m/s]	RAR	AcT [ms]	Acc [m/s^2]
Those cured	0	2.6 ± 0.3	3.6 ± 0.3	58.7 ± 9.1	2.6 ± 0.5
	I	1.4 ± 0.2‡	2.3 ± 0.4*;‡	35.0 ± 3.3§	6.4 ± 1.9
	II	1.3 ± 0.1‡	2.0 ± 0.2†	40.0 ± 5.0	4.9 ± 0.7§
	III	1.5 ± 0.1‡	1.7 ± 0.2†	48.8 ± 6.7	5.2 ± 1.3§
Those not cured	0	2.8 ± 0.2	3.9 ± 0.2	75.0 ± 9.4	3.4 ± 0.8
	I	1.0 ± 0.1†	1.5 ± 0.1*;†	36.1 ± 3.1†	6.6 ± 0.7†
	II	1.1 ± 0.1†	1.6 ± 0.1†	37.7 ± 3.3†	6.0 ± 1.3†
	III	1.3 ± 0.1†	1.8 ± 0.1†	45.9 ± 3.6†	5.2 ± 0.5†

Vmax, maximum systolic velocity, RAR, renal-aortic ratio, AcT, acceleration time, Acc, acceleration
Data are given as mean ± SEM
Statistical significance between the group cured and that not cured (*$p < 0.05$)
Statistical significance for the change within the group (§$p < 0.05$, ‡$p < 0.01$, †$p < 0.001$)

Groups 1 and 2, when taken as a whole, showed a statistically significant decrease in RAR after successful renal artery correction at I, II and III (Table II) and the values were within the normal limits after the correction. RAR was significantly higher in Group 1 as compared to Group 2 at I but not at 0, II and III.

Intra-renal branches

Evaluation of the intra-renal branches in the one year follow-up period revealed a decreased Acc value at 0 (the lower limit of the normal range being 3.5 m/s^2), followed by a statistically significant increase in Acc at I, II and III for Groups 1 and 2 taken as a whole (Table II). It should be noted that Acc remained within the normal range over one year at I, II, III but tended to decrease non-significantly. No statistically significant differences in Acc were noted between Group 1 and Group 2 on any of the four occasions (Table II).

AcT value was increased at 0 (the upper limit of the normal range being 60 ms) in the whole group and after successful renal artery correction a significant decrease was observed at I, II and III in the group taken as a whole and in Group 2. In Group 1 the mean AcT value remained within the normal range at baseline. A significant decrease in AcT was observed in Group 1 at I but not at II and III as compared to the baseline (Table II). No significant differences in AcT were observed between Group 1 and Group 2 (Table II).

Resistive index and pulsatility index

Taking the group as a whole, RI value at 0 decreased to 0.59 ± 0.02, below the 0.6, which was regarded as the lower limit of the normal range. RI values increased non-significantly at I, II, and III in comparison with the pre-interventional period (0.62 ± 0.02, 0.84 ± 0.05, 0.61 ± 0.02 vs. 0.59 ± 0.02 respectively; p = NS).

In Group 1 there were no differences in RI value at I, II, and III as compared with the baseline (0.54 ± ± 0.02, 0.56 ± 0.03, 0.55 ± 0.04 vs. 0.52 ± 0.04 respectively; p = NS). In Group 2 RI values increased non-significantly at I, II, and III as compared with the pre-interventional period (0.64 ± 0.02, 0.94 ± 0.05, 0.63 ± 0.02 vs. 0.61 ± 0.02 respectively; p = NS).

RI values were significantly higher in Group 2 as compared to Group 1 at 0 and I and there was a tendency for these to remain non-significantly elevated at II and III (Fig. 1).

For the whole group the PI value at 0 was 0.97 ± ± 0.05 (normal value being up to 1.0) and after successful renal artery correction a significant increase in PI was observed at I, II and III in comparison with the pre-interventional period (1.08 ± 0.06, 1.19 ± 0.12, 1.07 ± 0.06 vs. 0.97 ± 0.05 respectively; p < 0.05).

In Group 1 there were no differences in PI values at I, II, and III compared to the baseline (0.90 ± ± 0.05, 0.86 ± 0.10, 0.88 ± 0.11 vs. 0.79 ± 0.07 respectively; p = NS).

In Group 2 PI values increased non-significantly compared to the pre-interventional period (1.14 ± ± 0.07, 1.31 ± 0.16, 1.13 ± 0.08 vs. 1.04 ± 0.06) and were above the normal upper limit.

It should also be noted that there were significant differences in PI values between Groups 1 and 2 before and at 6 weeks (I) after successful renal artery correction (Fig. 2).

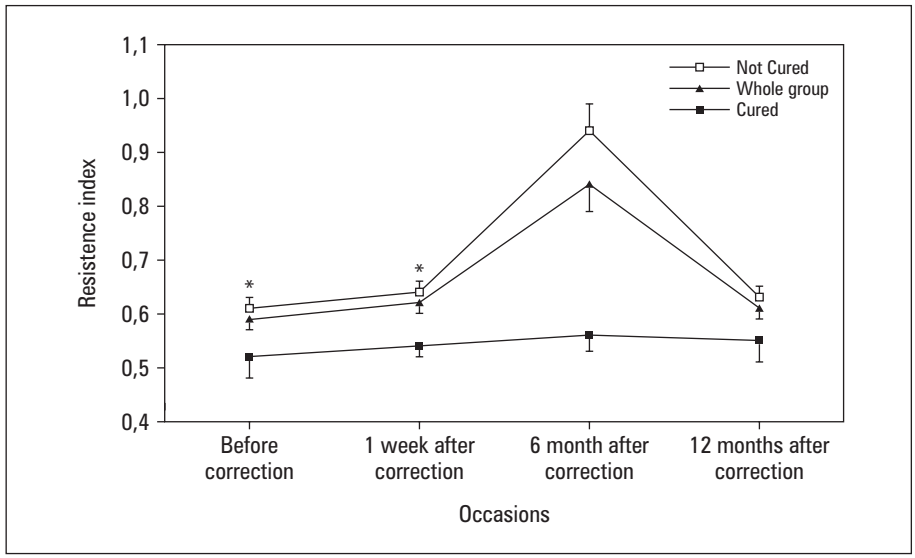

Figure 1. Resistive index of the whole group, those cured and those not cured. Data represent the mean ± SEM. Statistical significance between the group cured and that not cured at *p < 0.05

Rycina 1. Współczynnik oporności w całej grupie badanej, w grupie wyleczonej i niewyleczonej. Dane przedstawiono jako średnie ± SEM. Statystycznie istotne różnice między grupą wyleczoną i niewyleczoną: *p < 0,05

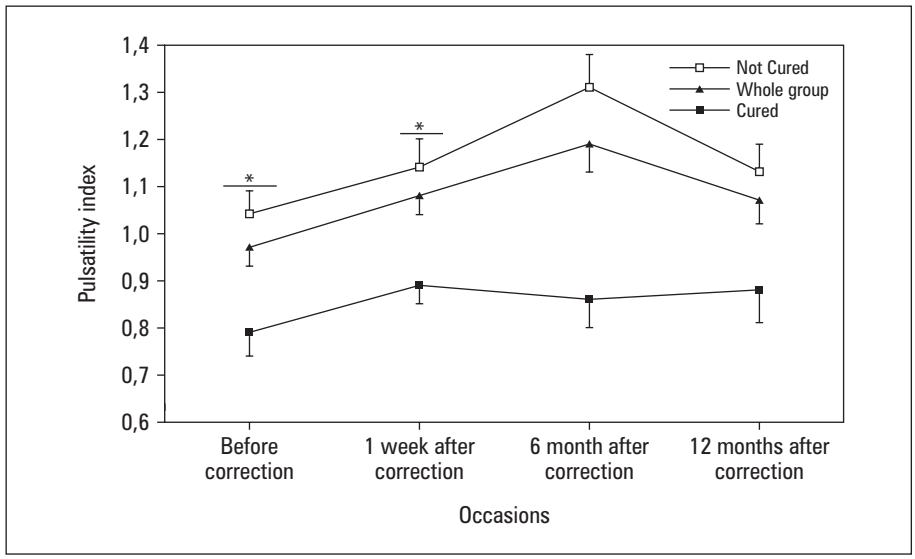

Figure 2. Pulsatility index of the whole group, the group and the group not cured. Data represent the mean ± SEM. Statistical significance between the group cured and that not cured at *p < 0.05

Rycina 2. Wskaźnik pulsacji w całej grupie badanej, w grupie wyleczonej i niewyleczonej. Dane przedstawiono jako średnie ± SEM. Statystycznie istotne różnice między grupą wyleczoną i niewyleczoną: *p < 0,05

Discussion

In the present prospective study we evaluated the effect of successful renal artery correction on intra-renal Doppler flow parameters in hypertensive patients with RAS and normal renal function.

The effect of angioplasty or surgical treatment on clinical outcome was also evaluated. In the group studied blood pressure normalised in 27% of hypertensive patients. It should be noted that our criteria differ from those of other reports and subjects were regarded as cured if antihypertensive treatment was discontinued and 24 h BP lowered to < 135/85 mm Hg following PTRA or surgery without the use of any antihypertensive medication. In other studies only improvement in blood pressure was evaluated with

no change or decrease in the number of antihypertensive drugs.

It should be noted that in all groups angioplasty or surgery was associated with a significant decrease in both Vmax and RAR, proving the success of renal artery correction.

In contrast to both resistive and pulsatility indices, a significant increase in acceleration was observed in all the groups studied and a significant decrease in acceleration time was noticed in the group as a whole and in Group 2.

Our results confirm the observations of other authors that this two intra-renal Doppler flow parameters mentioned above are useful in the follow-up of patients with RAS after angioplasty or surgical treatment of RAS [8].

Burdic *et al* reported superior accuracy for the acceleration and acceleration time with respect to the pulsatility index and resistive index in the detecting of renal artery stenosis. The authors conclude that acceleration and acceleration time are more accurately screened for RAS, probably because their alterations are less attenuated by the counterbalancing effects of age and of atherosclerosis [8].

Although it is not believed that duplex sonographic measurement of intra-renal flow patterns alone is an accurate means of assessing main renal artery occlusive disease, the resistive indices seem to reflect the extent of intra-parenchymal disease.

Our results indicate that successful renal artery correction had no significant effect on the resistive index in any of the groups investigated and affected non-significant the pulsatility index in Group 1 and Group 2.

Our data showed that both resistive and pulsatility indices were significantly higher in Group 2 in comparison with Group 1 before renal artery correction, which may suggest more advanced renal atherosclerotic disease.

There was also a tendency for the resistive index to remain non-significantly elevated during follow-up at 6 and 12 months after angioplasty or surgery.

However, since the group of patients who were cured was rather limited, none of the parameters, including the resistive and pulsatility indices, were evaluated in this study as predictors for blood pressure improvement.

Other clinical studies which assess resistance in the renal parenchyma with Doppler ultrasonography provide information for patients undergoing renal artery revascularisation [9–10].

Cohn *et al*. analysed resistance to flow in the renal parenchyma in 23 patients in whom 31 consecutive renal artery revascularisations (surgical in most cases) were performed. Duplex sonography was carried out in each subject before and after revascularisation and resistance was measured by parameters relating the end-diastolic velocity to the peak systolic velocity (the d/s ratio) [11]. In the group studied 21 subjects were hypertensive and a decrease in blood pressure was observed in 81% patients. The mean value of d/s before revascularisation was significantly higher in the patients cured or in those who improved as compared to those who failed to achieve improvement in blood pressure. The results suggest that a pre-interventional d/s ratio of less than 0.3 is correlated with clinical failure to improve blood pressure and renal function [11].

Frauchiger and colleagues showed in a group of 32 patients (35 renal interventions) that a d/s ratio of less than 0.3 is correlated with clinical failure in the treatment of hypertension by renal revascularisation. The results of the study indicated that a value higher than 0.3 has no prognostic relevance [12].

A significant difference was found in the d/s ratio between patients with atherosclerotic and fibromuscular dysplasia, which may be a consequence of more advanced age, longer duration of hypertension and additional risk factors in the atherosclerotic group.

Radermacher *et al.* reported that in a group of 138 patients with unilateral or bilateral renal artery stenosis, a renal resistive index value of at least 0,8 × 100% before revascularisation was associated with lack of improvement in blood pressure and a worsening of renal function [14]. Conversely, lower resistive index values were associated with an improvement in both blood pressure and renal function after the correction of renal artery stenosis during follow-up over one year.

It should, however, be noted that in the last instance a resistive index value of at least 0,8 × 100% was relatively high as compared to other reports. The comparison with our study is difficult since our patients were younger and had normal renal function in comparison with the larger group of patients described by Radermacher *et al*. [14].

In another study, that of Marana *et al.*, intra-renal echo-Doppler velocimetric indices were evaluated in 63 hypertensive patients with predominantly unilateral renal artery stenosis before and five days after ballon and/or stent implantation [13].

It is of interest that prior to dilatation no correlation was found between the degree of arterial narrowing in the arteries with atherosclerotic stenosis and any of the velocimetric indices.

Taken as a whole, our study indicates that among hypertensive patients with RAS and preserved renal function, successful renal artery correction had no effect on the resistive index and pulsatility index. Of the four indices examined acceleration and acceleration time are useful for evaluating the long-term results of renal angioplasty or surgical treatment in patients with RAS.

Abstract

Background The aim of this prospective study was to evaluate the effect of successful renal artery correction (angioplasty or surgery) on intra-renal Doppler flow parameters in hypertensive patients with renal artery stenosis (RAS) and preserved renal function.

Material and methods The study included 30 hypertensive patients (mean age: 53.5 ± 2.0 yrs, range: 33–75 years; 18 males, 12 females) with arteriographically confirmed atherosclerotic RAS. Intra-renal Doppler flow parameters (maximum systolic velocity — Vmax, acceleration — Acc, acceleration time — AcT, pulsatility index — PI and resistive index — RI) were evaluated before (0) and during a one year follow-up period at 1 week (I), 6 months (II) and 12 months (III) after successful renal artery correction (angioplasty or surgery) in hypertensive patients with RAS. 24-hour blood pressure monitoring was performed before and 12 months (at III) after RAS correction. The patients were classified into two groups according to the clinical outcome: Group 1 — cured, with permanent discontinuation of antihypertensive treatment and with 24 h BP of < 135/85 mm Hg following PTRA or surgery without antihypertensive medication; Group 2 — not cured, with antihypertensive treatment maintained or modified but not discontinued.

Results In Groups 1 and 2, taken as whole, a statistically significant decrease in Vmax was observed at I, II and III, as compared to the pre-intervention period. Evaluation of the intra-renal branches in the one year follow-up revealed a decreased Acc value at 0 followed by a statistically significant increase in Acc at I, II and III for the whole group involved in the study, taking Groups 1 and 2 together, as compared to the pre-interventional period. The AcT value for the whole group was increased at 0 and after successful renal artery correction a significant decrease was observed at I, II and III in the whole group and in Group 2. In Group 1 there were no differences in RI value at I, II, and III when compared with the baseline (0.54 ± 0.02, 0.56 ± 0.03, 0.55 ± 0.04 vs. 0.52 ± 0.04 respectively; p = NS). In Group 2 RI values increased non-significantly at I, II, and III, as compared to the pre-interventional period (0.64 ± 0.02, 0.94 ± 0.05, 0.63 ± 0.02 vs. 0.61 ± ± 0.02 respectively; p = NS). RI values were significantly higher in Group 2 as compared to Group 1 at 0 and I. There were significant differences in PI values between Group 1 and Group 2 before and 6 weeks (I) after successful renal artery correction.

Conclusion Our study indicates that among hypertensive patients with RAS and preserved renal function successful renal artery correction had no effect on the resistive index and pulsatility index. Of the four indices examined acceleration and acceleration time are useful for evaluating the long-term results of renal angioplasty or surgical treatment in patients with RAS.

key words: renal artery stenosis, angioplasty, surgical treatment, Doppler, duplex, intra-renal parameters

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