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Preliminary report on Doppler quantification of peripheral vascular resistance in patients with thromboangiitis obliterans, the diagnostic value of high resistance index – HRI

Wartość diagnostyczna pomiarów dopplerowskich indeksu wysokooporowego (HRI) w tętnicach kończyn dolnych u chorych z zakrzepowo-zarostowym zapaleniem naczyń (TAO) – doniesienie wstępne

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Summary

Background: HRI is a new vascular resistance parameter, showing the ratio between peak diastolic flow reversal velocity (D) and peak systolic velocity (S) – HRI=D/S. The aim of our study was to assess diagnostic value of HRI calculated from Doppler spectrum of popliteal arteries in patients with thromboangiitis obliterans (TAO), compared with control group of healthy subjects.

Material/Methods: During 4–year period (1998–2001) 80 patients underwent duplex Doppler US – 40 with confirmed TAO and 40 healthy subjects. Examinations were done with 5–10 MHz transducer under standardised conditions: correct Doppler angle, sample volume size, the same patient's position, after 10–minute muscle rest.

Results: HRI values in control group of patients varied from 0.264 to 0.586 – average 0.412. In patients with TAO, HRI was significantly decreased – from 0.088 to 0.380 – average 0.228. We also found positive correlation between the decrease of HRI values and clinical advancement of the disease. 16 patients with long-lasting TAO (6–15 years) had average HRI = 0.136. 24 patients with shorter disease duration had average HRI = 0.276.

Conclusions: TAO affects middle-sized resistive arterioles. Thus, blood flows to collateral, low resistance cutaneous arteries. That is why we observed decrease of vascular resistance in patients with TAO. HRI can be useful Doppler parameter in early diagnosis of TAO and probably in monitoring disease progression.

key words: **duplex Doppler ultrasound • vascular resistance • thromboangiitis obliterans**

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Background

Thromboangiitis obliterans (TAO; Buerger's disease) is an inflammatory vascular disease known for almost a hundred years but there are still a lot of controversies around it. First come etiology and pathogenesis which has not yet been finally established. Another, is lack of uniform diagnostic criteria, non-typical course of the disease and eventually problems with its successful treatment [1–3].

In general, a patient with TAO is a young male who is a heavy user of tobacco presenting distal extremity ischemia. Additional factors like excluded atherosclerosis, diabetes or trauma, absence of connective-tissue disease and also frequent presence of migratory thrombophlebitis make clinical diagnosis highly probable [4–6]. Angiography helps to diagnose TAO by showing occluded distal small and medium-sized arteries of the extremities with undiseased arteries proximal to popliteal or distal brachial level. Images of corkscrew collaterals in angiography are distinctive (Figure 1). Abnormal digital plethysmographic waveforms are also highly suggestive, especially in patients with excluded diabetes or renal failure [3,7,8]. In microscopic studies, findings of nonnecrotizing arterial wall inflammation associated with intraluminal thrombosis are typical. Unfortunately, there is no consensus which process is the initiating event in the disease [9–11]. Because not all smokers develop TAO and because of demographic prevalence it has been suggested that some patients may have genetic predisposition. Other investigators suggest also immunologic basis of TAO, but there is still not enough support for these theories [12,13].

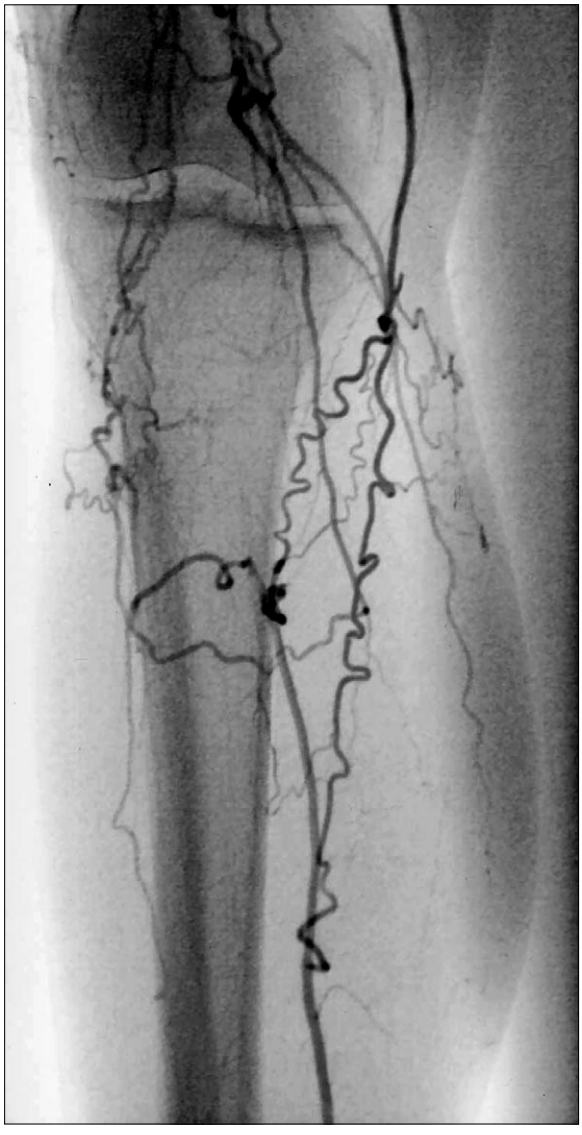


Figure 1. Typical DSA image of lower extremity arteries in TAO patient. Occlusion of main arteries and cork-screw collaterals.

Rycina 1. Typowy obraz TAO w cyfrowej angiografii subtrakcyjnej. Niedrożność głównych pni tętniczych i kręte tętnice skórnego krążenia obocznego.

The course of TAO is usually characterised by periods of clinical remissions interspersed with relapses, what corresponds well with cessation and resumption of smoking. Thus, tobacco abstinence is a basis of all therapy of TAO. Any medical or surgical therapy is ineffective unless smoking is definitely quit. Because of disappointing results of bypass procedures there is some value of sympathectomy in improving cutaneous blood flow but its effects are unpredictable. Adequate pain management during relapse periods is still the main part of medical therapy. Administration of vasodilatators, prostaglandins, platelet inhibitors, anticoagulants and anti-inflammatory agents result only in some patients as occasional benefits [14–16]. Finally, the majority of patients, especially these who did not quit smoking, amputation is required because of uncontrollable infection or gangrene. Although, it is always considered to maximise limb salvage, the result remains tragic in all these cases – physical and social disability [17,18].

Like in any other diseases proper and early diagnosis is crucial for applying therapy as successful as possible. As mentioned, there are a lot of tests to diagnose TAO, but none of them is of great value as a single one. Duplex Doppler ultrasound proved in the last years to be very useful in diagnosing many vascular pathologies. In case of TAO its role is generally limited to find the level of main artery occlusion and in evaluating possible atherosclerosis in proximal arterial bed. Vascular resistance calculation using Doppler method is not yet used as a routine test in diagnosis of TAO. Arterial bed of the extremities is typically an area of high resistance to flow. Normal Doppler spectral waveforms of lower limb arteries show typically positive systolic peak (forward flow) and negative early diastolic peak (reversed flow). The high resistance is caused by muscular arterioles so-called 'resistive arterioles'. Thus, when blood flows to muscles at rest Doppler spectral waveform shows negative early diastolic peak. There is also a third positive diastolic peak, commonly but not always seen in such spectral waveforms. This peak does not show vascular resistance and it is out of interest during high resistance quantification [19,20]. There are a few Doppler indices being used in flow resistance quantification. Each of them (RI, PI, S/D, A/B) can measure areas with low–resistance to flow, like brain, placenta, liver or kidneys but only pulsatility index (PI) can be used in assessing Doppler waveforms without end–diastolic flow or with diastolic negative flow. Unfortu-

nately, quantification of PI is pretty complicated and its values are strongly influenced by heart rate and blood pressure changes [21]. Conversely, a new vascular resistance parameter (high resistance index HRI) defined and validated on an animal model in 1995 by Arbeille et al. is easy to calculate as a simple ratio between the maximal early diastolic reversed flow velocity (D) and the maximal systolic forward flow velocity (S) – HRI = D/S. What is also important, that HRI does not depend on Doppler angle, heart rate and blood pressure changes [1,20,22].

Thromboangiitis obliterans affects small and medium–sized arteries and also 'resistive arterioles' causing its thrombosis. This looked for us obvious, that such mechanism was to change the resistance to flow in the extremities. When we read the paper by Arbeille et al. on the new high resistance index we got an idea to calculate it in our TAO patients. Thus, the paper presents below the results of our preliminary study on high resistance index quantification in patients suffered from TAO.

Material and Methods

During a 4-year period (1998–2001) 80 patients underwent bilateral duplex Doppler US examinations of lower extremity arteries: 40 patients with confirmed diagnosis of TAO and 40 healthy subjects as a control group. Patients with TAO were 34 men and 6 women, aged from 38 to 57 (average 45). Control group of patient were the same number of men and women, approximately at the same age (average 43).

Among patients who suffered from TAO, 16 had long-lasting course of the disease (6 to 15 years) and the remaining 24 had shorter disease duration time (1 to 5 years). All these patients were heavy smokers with the initial episode of distal extremity ischemia at the age of 31 to 46 (average 36). In all the cases the diagnosis was based on clinical and anamnesis data (specified in the Introduction). Angiography (DSA) was to confirm diagnosis in all the patients (Figure 1). Plethysmographic examinations were performed in 26 of TAO patients and in all of them obtained waveforms were abnormal. Doppler examinations were performed in TAO patients during routine control visits. 37 patients were examined in their disease remission and 3 patients during hospitalisation because of relapse into TAO. All the TAO patients were under medical therapy, 32 underwent previous sympathectomy and 18 had amputation (12 – minor amputation concerning toes and 6 – major amputation concerning foot or more).

All the duplex Doppler examinations were done with Logiq 500 (General Electric) using 5–10 MHz transducer under standardised conditions: correct Doppler angle and sample volume size, with the same patient's position (horizontal supine), after 10 minute muscle rest. Doppler spectral waveforms were always obtained bilaterally from lower extremity arteries proximally to main artery trunk occlusion. The level of occlusion was known from angiographic images. In 27 TAO patients spectral waveforms were taken from popliteal arteries and in the remaining 13 patients from distal parts of superficial femoral arteries. In all healthy subjects popliteal arteries were bilaterally examined.

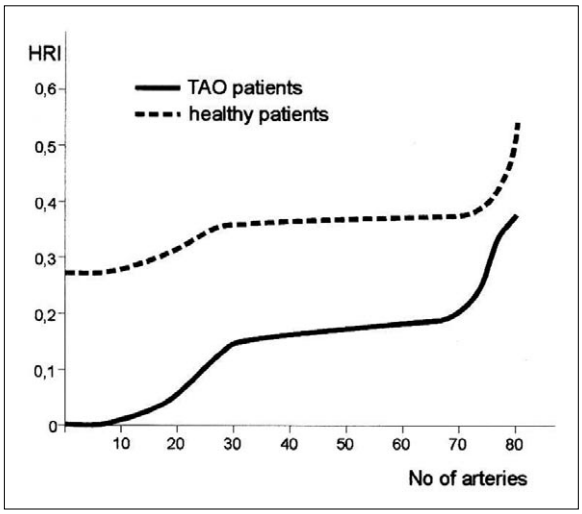


Figure 2. HRI values in patients suffered from TAO and in healthy subjects.

Rycina 2. Zebrane na wykresie wartości HRI u chorych z TAO i u ludzi zdrowych z grupy kontrolnej.

We calculated HRI value in all 160 lower extremity arteries after a precise measurement of peak velocities of diastolic negative flow (D) and systolic forward flow (S).

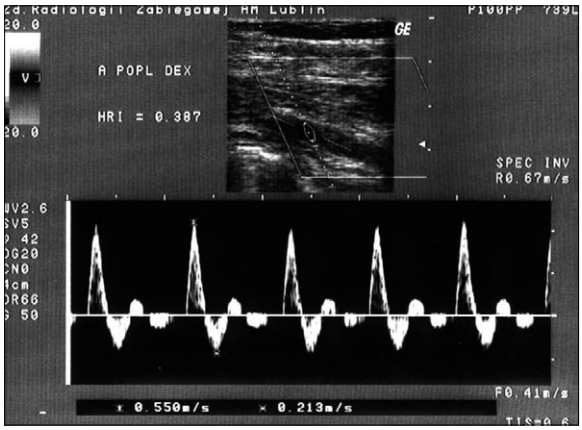
Among our TAO patients, 19 had symptoms of upper extremity ischemia, and we did perform duplex Doppler examinations of upper extremity arteries. We collected the data but it was not taken into consideration to avoid blurring our preliminary report.

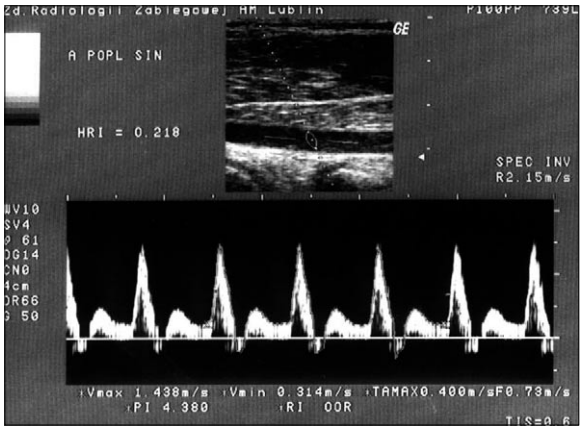
Results

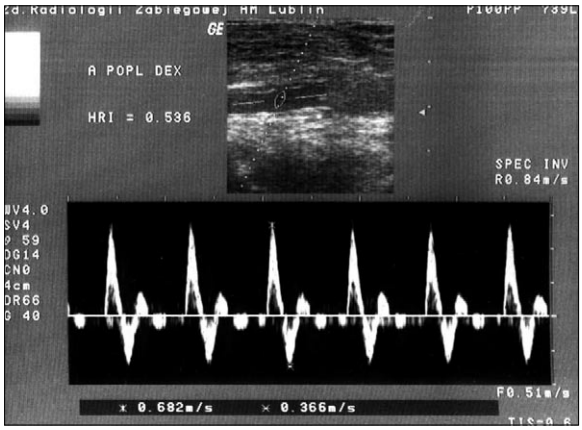
Figure 2 shows a diagram with two curves of HRI values calculated from Doppler spectral waveforms of lower extremity arteries in the control group of healthy patients and in patients suffered from thromboangiitis obliterans.

HRI values in the control group of healthy patients varied from 0.264 to 0.586 – average 0.412. The range of normal HRI values was wide, but the appropriate curve on Figure 2 showed that, the majority of calculated values oscillate between 0.350 and 0.500 (Figure 3). What we also found, was that HRI values of both legs in the same healthy patients were almost symmetric. We noticed the highest difference of only about 20% in HRI calculation between right and left leg in the same patient.

In patients suffering from TAO, HRI values were significantly decreased – from 0.088 to 0.380 – average 0.228 (Figure 4). The distinctive finding was also HRI asymmetry between both legs, what was noticed in 34 (85%) out of 40 TAO patients. The asymmetry of HRI values exceed 20% in all these patients and lower HRI corresponded well with more advanced clinical status of the leg. In 7 patients spectral waveforms taken from superficial femoral arteries of amputated legs (7 major amputations) showed a very low resistance without reversed diastolic peak. In these cases HRI value was 0 (Figure 5). These values of 0 (7 out of 80)







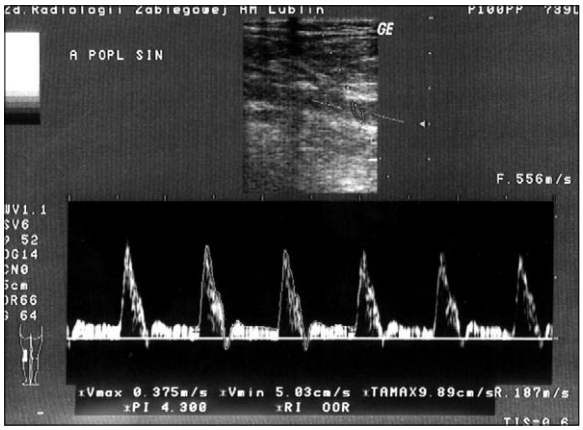
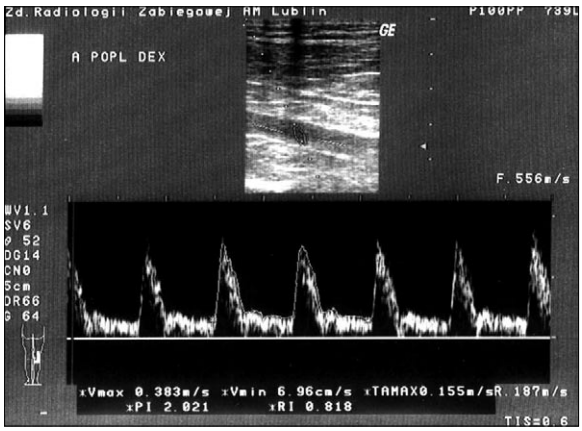


Figure 3a,b. Normal Doppler spectral waveforms taken from popliteal arteries of healthy patients. HRI values – 0.387 and 0.536.

Rycina 3a,b. Wykresy prawidłowego spektrum dopplerowskiego uzyskane z tętnic podkolanowych ludzi zdrowych z grupy kontrolnej. Wartości HRI – 0.387 i 0.536

Figure 4a,b. Abnormal Doppler spectral waveforms of popliteal arteries in patients suffered from TAO. Clearly visible early diastolic reversed flow reduction and distinctive decrease of HRI values of 0.218 and 0.134.

Rycina 4a,b. Nieprawidłowe wykresy spektrum dopplerowskiego uzyskane z tętnic podkolanowych chorych z TAO. Redukcja odwróconego przepływu rozkurczowego, wartości HRI – 0.218 i 0.134.



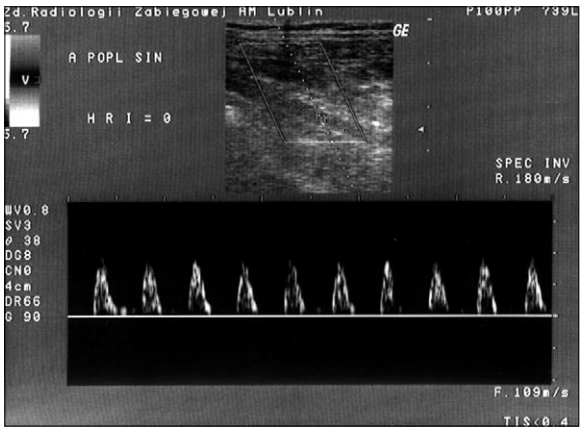


Figure 5. Popliteal Doppler spectral waveforms without diastolic flow reversal – HRI=0; a) Patient with long-lasting TAO – low-resistance waveform with continuous, positive diastolic flow; b) Doppler spectral waveform taken from popliteal artery during disease relapse time – systolic peaks only.

Rycina 5. Wykresy spektrum dopplerowskiego bez sygnału przepływu odwróconego w fazie rozkurczu – HRI=0. a) Chory z długim przebiegiem TAO – wykres dopplerowski niskooporowego przepływu krwi w fazie skurczowej i rozkurczowej. b) Wykres dopplerowski u chorego z zaostrzeniem choroby – widoczne jedynie piki skurczowe.

were not taken for average HRI calculation but they are illustrated on the appropriate curve on Figure 2.

We also found a positive correlation between clinical advancement of the disease (proportional to disease duration) and the decrease of HRI values. In16 patients with long-lasting TAO (6 to 15 years – mean 8 years) average HRI was 0.136. In the remaining group of 24 patients with shorter disease duration (1 to 5 years – mean 3 years) an average HRI was 0.276.

Discussion

Before we started the study, we expected, that vascular resistance to flow in extremities affected with thromboangiitis obliterans was to be higher than in the undiseased extremities. Such thinking was based on previous studies done on animal model with tests performed to induce vascular resistance changes. It was adrenalin administration for vasoconstriction and compression tests to reduce venous outflow. Both tests were done to reduce arterial blood flow and during these experiments a decrease of systolic peak amplitude (S) on Doppler spectral waveforms was noticed. Moreover, reversed diastolic flow amplitude was in these cases slightly (compression test) or significantly (adrenalin injection) increased. Finally, these experiments resulted in a great increase of HRI values [20].

The results obtained in our study on TAO patients were totally different. We found in Doppler spectral waveforms a reduction of reversed diastolic flow amplitude without significant decrease of peak systolic amplitude. HRI values calculated from such waveforms were significantly decreased in opposition to what we initially expected. We realised that hemodynamic situation in TAO patient differs from above mentioned experimental studies. Thrombosis of distal medium-sized arteries and small 'resistive arterioles' seen in TAO results in extremity ischemia, what coerce circulation into collaterals to protect extremity from gangrene. Collateral arteries are mainly cutaneous, which are low-resistance and that is the most likely explanation of the observed decreased HRI values in TAO patients [22,23].

High resistance index is the ratio between two most stable parameters of Doppler spectral waveform: systolic and diastolic peaks. It is also independent on general circulation conditions like heart rate and blood pressure changes. These features determine that the HRI values are very representative for the vascular resistance, much more sensitive and reproducible than other Doppler resistance indices, particularly pulsatility index (PI) [20]. The main drawback is, that HRI can evaluate high vascular resistance only in the absence of stenosis or occlusion proximal to measuring point, because proximal obstruction reduces development and propagation of the reverse pressure. That explains, why post-stenotic spectral waveforms do not show reversed flow peak - necessary for HRI calculation. For this reason HRI is not useful in assessing atherosclerotic arteries.

Conclusions

Our preliminary study proved that Doppler calculation of HRI is a useful parameter in noninvasive confirmation of complex TAO diagnosis. Nevertheless, HRI calculation is not specific for TAO but its abnormal values, especially when asymmetric, can improve diagnostic process when compared with other clinical and instrumental features of TAO.

We also state, that monitoring of blood flow resistance using Doppler HRI in patients suffered from TAO may help to evaluate a possible disease progression, but this need more study

In conclusion, we found the Doppler HRI well adapted to noninvasive, real-time evaluation of vascular resistance in lower limbs affected with thromboangiitis obliterans.

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