

Abstract

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INTRAVENOUS LASER THERAPY IN A COMPREHENSIVE APPROACH TO THE CORRECTION OF RISK FACTORS OF ARTERIAL HYPERTENSION

Introduction. According to Akl C et al. by 2025, the number of people with arterial hypertension (AH) will increase by 15–20% and reach 1.5 billion people. Since hyperuricemia (HU) is closely related to other AH risk factors, there is a need to study the relationship between HU and other AH risk factors. **Objective** of this work is to develop rational approaches to modifying individual AH risk factor using intravenous laser therapy (IVLT).

Materials and methods. The study included 184 people: Group 1 (n = 30) – normotensive individuals without HU; Group 2 (n = 52) – normotensive patients with HU; Group 3 (n = 48) – patients with essential AH (stage I, 1-2 degree) without HU; Group 4 (n = 54) – patients with essential AH (stage I, 1-2 degree) with HU. Patients in Group 3 and 4 were divided into subgroups according to the treatment regimens: 3A (n = 24), 4A (n = 26) (standard antihypertensive therapy (AHT)) and 3B (n = 24), 4B (n = 28) (combination treatment with AHT and IVLT). The IVLT course was performed with a wavelength of 635 nm, a power of 1.5 mW, a radiation power density of 0.2 W/cm², a fluence of 0.2 J/cm², an exposure of 900 seconds, the course – daily, with a total of 10 procedures.

Study results. The association between the level of uric acid (UA), systolic blood pressure (SBP), diastolic blood pressure (DBP), endothelial dysfunction (ED), left ventricular myocardial dysfunction, excess increase in arterial wall stiffness, and poikilocytosis in the study groups was established. The use of IVLT in combination with AHT allows to achieve a statistically significant ($p < 0.05$), compared to AHT reduction in SBPd by 4.2%, DBPd by 2.4%, DBPn by 2.5%, time index (TI) SBPd by 5.1%, TI DBPd by 2.7%, TI SBPn by 19%, rate of morning rise (RMR) SBP by 33.8%, RMR DBP by 31%, early morning blood pressure surge (EMBPS) SBP by 17.3%,

EMBPS DBP by 12.8%, pulse wave velocity (PWV) by 4.1%, manifestations of endothelial dysfunction by 1.4%, myocardial dysfunction by 4.5%, poikilocytosis by 2.9%, uric acid level by 3.1% in patients with AH. In AH and HU comorbidity, addition of ILT to AHT allows to achieve an additional reduction in SBPd by 9.3%, DBPd by 7.4%, SBPn by 11.5%, DBPn by 2.7%, TI SBPd by 18.8%, TI DBPd by 18.9%, TI SBPn by 1.8%, TI DBPn by 8.7%, RMR SBP by 25.8%, RMR DBP by

28.5%, EMBPS SBP by 8.2%, EMBPS DBP by 6.0%, PWV by 13.4%, endothelial dysfunction by 3.5%, myocardial dysfunction by 18.8%, poikilocytosis by 5.7%, uric acid level by 11.6% compared to AHT. In patients with normal blood pressure and HU values, the use of IVLT can reduce DBPM, EDVD, poikilocytosis, and UA level parameters ($p < 0.05$).

Conclusions. The presence of direct correlations of average strength between HU and endothelial dysfunction, systolic diastolic dysfunction, excessive increase in arterial wall stiffness, and poikilocytosis was found. The use of IVLT in normotensive and hypertensive patients with AH with an effective method of UA level correction, excessive arterial wall stiffness, myocardial dysfunction, ED and poikilocytosis.

Keywords: intravenous laser therapy, IVLT, arterial hypertension risk factors, hyperuricemia, endothelial dysfunction, arterial wall stiffness, systolic and diastolic dysfunction, poikilocytosis.

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Резюме

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ВИКОРИСТАННЯ НИЗЬКОІНТЕНСИВНОЇ ВНУТРІШНЬОВЕННОЇ ЛАЗЕРНОЇ ТЕРАПІЇ У КОМПЛЕКСНОМУ ПІДХОДІ ДО КОРЕКЦІЇ ФАКТОРІВ РИЗИКУ АРТЕРІАЛЬНОЇ ГІПЕРТЕНЗІЇ

Вступ. За даними Akl C et al. до 2025 року кількість людей з артеріальною гіпертензією (АГ) збільшиться на 15–20 % та досягне 1,5 млрд чоловік. Так як гіперурикемія (ГУ) тісно пов'язана з іншими факторами ризику АГ, існує необхідність вивчити взаємозв'язки між ГУ та іншими факторами ризику АГ.

Метою роботи є розробка раціональних підходів до модифікації окремих факторів ризику АГ з використанням внутрішньовенної лазерної терапії (ВЛТ).

Матеріали і методи. У дослідження було включено 184 особи: 1 група ($n = 30$) – нормотензивні особи без ГУ; 2 група ($n = 52$) нормотензивні пацієнти з ГУ; 3 група ($n = 48$) пацієнти з есенціальною АГ (I стадія, 1–2 ступінь) без ГУ; 4 група ($n = 54$) пацієнти з есенціальною АГ (I стадія, 1–2 ступінь) з ГУ. Пацієнти 3 та 4 групи були розподілені на підгрупи у відповідності до схем лікування: 3А ($n = 24$), 4А ($n = 26$) (стандартна антигіпертензивна терапія (АГТ)) та 3Б ($n = 24$), 4Б ($n = 28$) (комбіноване лікування АГТ та внутрішньовенна лазерна терапія (ВЛТ)). Курс ВЛТ проводили з довжиною хвилі 635 нм, потужність 1,5 мВт, щільність потужності випромінювання $0,2 \text{ Вт/см}^2$, флюєнс $0,2 \text{ Дж/см}^2$, експозицією 900 сек, курс – щоденно, загальною кількістю 10 процедур.

Результати дослідження. Встановлено наявність асоціації між рівнем сечової кислоти (СК), систолічного артеріального тиску (САТ), діастолічного артеріального тиску (ДАТ), ендотеліальною дисфункцією (ЕД), дисфункцією міокарду лівого шлуночка, понаднормовим підвищенням жорсткості артеріальної стінки, пойкилоцитозом у досліджуваних групах. Використання ВЛТ у поєднанні з АГТ дозволяє досягти статистично значимішого ($p < 0,05$), порівняно із АГТ зниження САТд на 4,2 %, ДАТд на 2,4 %, ДАТн на 2,5%, індексу часу (ІЧ) САТд на 5,1 %, ІЧ ДАТд на 2,7 %, ІЧ САТн на 19 %, швидкості ранкового підйому (ШРП) САТ на 33,8%, ШРП

ДАТ на 31%, величини ранкового підйому (ВРП) САТ на 17,3%, ВРП ДАТ на 12,8%, швидкості пульсової хвилі (ШПХ) на 4,1%, прояви ендотеліальної дисфункції на 1,4 %, систолодіастолічної дисфункції на 4,5%, пойкилоцитозу на 2,9 %, рівня сечової кислоти на 3,1 % у пацієнтів з АГ. При коморбідності АГ та ГУ додавання ВЛТ до АГТ дозволяє досягти додаткового зниження САТ_д на 9,3 %, ДАТ_д на 7,4 %, САТ_н на 11,5 %, ДАТ_н на 2,7 %, ІЧ САТ_д на 18,8 %, ІЧ ДАТ_д на 18,9 %, ІЧ САТ_н на 1,8 %, ІЧ ДАТ_н на 8,7 %, ШРП САТ на 25,8 %, ШРП ДАТ на 28,5%, ВРП САТ на 8,2 %, ВРП ДАТ на 6,0 %, ШПХ на 13,4 %, ендотеліальної дисфункції на 3,5 %, систолодіастолічної дисфункції на 18,8 %, пойкилоцитозу на 5,7 %, рівня сечової кислоти на 11,6 % у порівнянні з АГТ. У пацієнтів з нормальними значеннями АТ та ГУ застосування ВЛТ дозволяє знизити показники ДМАТ, ЕЗВД, пойкилоцитозу, рівня СК ($p < 0,05$).

Висновки. Встановлена наявність прямих кореляційних зв'язків середньої сили між ГУ та ендотеліальною дисфункцією, систолодіастолічною дисфункцією, понаднормовим підвищенням жорсткості артеріальної стінки, пойкилоцитозом. Використання ВЛТ у нормотензивних та гіпертензивних пацієнтів з ГУ з ефективним методом корекції рівня СК, понаднормової жорсткості артеріальної стінки, систолодіастолічної дисфункції, ЕД та пойкилоцитозу.

Ключові слова: низькоінтенсивна внутрішньовенна лазерна терапія, фактори ризику артеріальної гіпертензії, гіперурикемія, ендотеліальна дисфункція, жорсткість артеріальної стінки, систолодіастолічна дисфункція, пойкилоцитоз.

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Introduction

According to Akl C et al. by 2025, the number of people with arterial hypertension (AH) will increase by 15–20% and reach 1.5 billion people [1]. In 2017, the European ESC/ESH Association added hyperuricemia to the existing risk factors of AH [2]. Since HU is closely related to other risk factors of AH, there is a need to further study the relationship between AH, HU, endothelial dysfunction (ED), systolic dysfunction, arterial wall stiffness, and changes in red blood cell morphology.

Since the 60s of the 20th century, low-intensity laser therapy, as a method of world physiotherapy, is used in almost all areas of preventive medicine and rehabilitation due to the evidence-based effect of non-specific photobiomodulation. During this period, the world literature has formed an evidence base for the safety of using low-intensity laser light, and further research expands the indications for its use. Studies, conducted on practically healthy individuals, demonstrate the protective effect of radiation with a wavelength of 660 nm [3]. A

randomized, single-center, blind, placebo-controlled study, which was conducted on practically healthy women and was approved by the Canadian Bioethics Commission SHIELD, revealed a high efficiency of photobiomodulation using a wavelength in the range of 400–470 nm to correct the effects of photoaging. The results indicate that photobiomodulation is not only effective, but also safe and painless [4].

The use of combined treatment regimens that complement standard therapy with physiotherapy methods is becoming increasingly evident, including in the primary prevention of AH.

The objective of this work is to evaluate the effectiveness of intravenous laser therapy (IVLT) in modifying individual risk factors of AH.

Materials and methods

184 people were selected to form research groups: Group 1 ($n = 30$) – normotensive individuals without HU; Group 2 ($n = 52$) – normotensive patients with HU; Group 3 ($n = 48$) – patients with essential hypertension (stage I, 1–2

degree) without HU; Group 4 (n = 54) – patients with essential AH (stage I, 1–2 degree) with HU.

The presence of AH was confirmed by blood pressure measurement at a family physician's appointment followed by daily blood pressure monitoring (DBPM). The absence or presence of HU was confirmed by performing a biochemical study to determine the level of uric acid (UA) in the blood serum. HU was considered the level of UA \geq

400 $\mu\text{mol/l}$ (6.8 mg/dl), which corresponds to the threshold of UA crystallization in the human body without taking gender into account [5]. Patients in Group 3 and 4 were divided into subgroups according to the treatment regimens: 3A (n = 24), 4A (n = 26) (standard AHT according to national protocols) and 3B (n = 24), 4B (n = 28) (combination treatment with AHT and ILT) (Table 1).

Table 1 – General characteristics of the studied groups

Indicator, unit	Group			
	1	2	3	4
Quantity	n = 30	n = 52	n = 48	n = 54
Age, years	48 \pm 5.5	49 \pm 4.9	49 \pm 5.1	51 \pm 4.8
Gender, male, n (%)	16 (53)	24 (49)	23 (48)	25 (49)
Risk according to SCORE scale (%) male/female	1.02/0.25	1.49/0.38	1.92/0.50	3.43/0.91
TC, mmol/l	4.47 \pm 0.826	4.67 \pm 0.932	4.62 \pm 0.612	5.98 \pm 0.721 ^{1,3,5}
TC LDL, mmol/l	3.11 \pm 0.730	3.33 \pm 0.615	3.61 \pm 0.515	4.29 \pm 0.526 ^{1,3,5}
TG, mmol/l	0.62 \pm 0.232	0.89 \pm 0.212	1.26 \pm 0.321	1.68 \pm 0.241 ^{1,3,5}
BMI, kg/m ²	22.5 \pm 4.45	23.2 \pm 3.32 ²	23.8 \pm 4.88	23.2 \pm 4.29
UA, $\mu\text{mol/l}$	298.5 \pm 18.25	457.3 \pm 12.54 ^{1,3}	365.8 \pm 15.62 ^{1,5}	498.5 \pm 18.31 ^{1,3,5}
GFR, ml/min/1.73m ²	106.2 \pm 21.32	110.5 \pm 22.12	109.4 \pm 20.54	112.4 \pm 18.35
SBPd, mm Hg	120.4 \pm 5.24	132.3 \pm 6.36 ¹	146.2 \pm 5.32 ^{1,5}	152.3 \pm 7.48 ^{1,3,5}
DBPd, mm Hg	74.2 \pm 4.25	82.5 \pm 4.65 ¹	92.4 \pm 2.36 ^{1,5}	96.4 \pm 5.29 ^{1,4,5}
HbA1*, %	4.8 \pm 0.58	4.6 \pm 0.71 ²	4.5 \pm 0.62	5.0 \pm 0.68
Capillary blood glucose, mmol/l	3.8 \pm 0.75	3.9 \pm 0.86 ²	4.1 \pm 0.87	4.0 \pm 0.82
Hemoglobin, g/l	131.2 \pm 6.85	128.4 \pm 7.22 ²	130.1 \pm 7.89	125.3 \pm 9.62
Red blood cells, 10 ¹² /l	4.2 \pm 0.89	4.4 \pm 0.77	4.8 \pm 0.83	4.7 \pm 0.92

Notes:

¹ – reliability of differences compared to the Group 1 indicator (p < 0.05);

² – reliability of differences compared to the Group 1 indicator (p < 0.05);

³ – reliability of differences compared to the Group 3 indicator (p < 0.05);

⁴ – reliability of differences compared to the Group 3 indicator (p < 0.05);

⁵ – reliability of differences compared to the Group 2 indicator (p < 0.05);

TC – total cholesterol; LDL – low density lipoproteins; TG – triglycerides; BMI – body mass index; GFR – glomerular filtration rate

All patients and individuals in the comparative group provided informational consent to participate in the study in accordance with the Helsinki Declaration of the World Medical Association "Ethical Principles for Medical Research Involving Human Subjects".

Laboratory blood tests (clinical, lipidogram, creatinine, uric acid, glucose) were performed according to standard methods using a semi-automatic analyzer RT-9800. Blood smear microscopy describing the morphology of elements was performed using Nikon SMZ-2 2B light

microscope (Japan). The number of poikilocytes was calculated using Goryaev chamber.

Daily blood pressure monitoring was performed in all groups for 24 hours using the oscillometric method with the (ABMP-50) HEACO apparatus. A test with reactive hyperemia to determine endothelium-dependent vasodilation (EDVD) was performed using ultrasound device SonoScape S6Pro and sphygmomanometer Little Doctor LD-SO13. The criteria of vasomotor endothelial dysfunction were the absence of an increase in the diameter of the brachial artery by more than 10% in response to a test with reactive hyperemia or the

appearance of vasoconstriction. Standard echocardiographic examination was performed using the ultrasound machine SonoScape S6Pro. The myocardial function of the left ventricle was determined using a non-invasive echocardiographic test with the determination of Tei index.

The ILT course was performed using a sterile light guide with a diameter of 500 microns daily, with a total of 10 procedures. ILT mode: the wavelength is 635 nm, output power of the light guide 1.5 mW, the power density in continuous mode is 0.2 W/cm², fluence in 0.2 J/cm², the total radiation dose is up to 180 J/cm², exposure time is 900 sec.

Statistical processing of the obtained research results was carried out using the statistical analysis software package Windows 10-Office Professional Plus in accordance with the license agreement with Microsoft (Agreement ID: V0731528). Spearman's rank correlation coefficient is used to identify and evaluate the strength of relationships between two sets of comparable quantitative indicators. To calculate the dynamics of changes in parameters, the method of calculating the Delta percent using the Percentage Change Calculator was used. To compare two independent samples by the level of any quantitatively measured feature, a nonparametric statistical criterion – the Mann – Whitney U-test was used. To evaluate the differences between the two dependent samples the

Wilcoxon test was used. The data in the tables is presented as: M ± SD. Relative risk (RR) is calculated as the ratio of absolute risks in the groups of exposed and non-exposed persons.

Study results

In order to establish correlations between the studied risk factors, Spearman's rank correlation coefficient was calculated in the studied groups: in Group 2, a direct relationship of average strength between the level of UA and SBP ($r = 0.49$, $p < 0.05$), DBP ($r = 0.35$, $p < 0.05$), pulse wave velocity (PWV) ($r = 0.58$), myocardial dysfunction ($r = 0.64$), poikilocytosis level ($r = 0.42$) and the inverse relationship of average strength with endothelial dysfunction ($r = -0.52$) ($p < 0.05$ for all) was revealed.

In Group 3, a direct relationship of average strength between the level of UA and SBP ($r = 0.32$, $p < 0.05$), DBP ($r = 0.29$, $p < 0.05$), PWV ($r = 0.34$), myocardial dysfunction ($r = 0.47$), poikilocytosis level ($r = 0.69$) and the inverse relationship of average strength with endothelial dysfunction ($r = -0.35$) ($p < 0.05$ for all) was similarly found.

In Group 4, in the presence of AH and HU, a similar orientation of correlations with a high level of confidence ($p < 0.001$) was found in the pairs UA – DBP, UA – endothelial dysfunction (EDVD) (Table 2).

Table 2 – Level of correlation (r) between modified risk factors of arterial hypertension in patients with AH and HU

Indicator	Uric acid	SBP	DBP	Tei index	EDVD	PWV	Poikilocytosis
Uric acid	+	0.22 ¹	0.17 ²	0.15	-0.35 ¹	0.34 ¹	0.41 ¹
SBP	0.48 ³	+	0.61 ¹	0.12	-0.32 ²	0.24 ¹	0.31 ¹
DBP	0.33 ¹	0.82 ¹	+	0.10 ²	-0.24 ¹	0.38 ¹	0.34 ¹
Tei Index	0.47 ¹	0.28 ¹	0.22 ²	+	-0.35 ¹	0.31 ¹	0.64 ¹
EDVD	-0.63 ³	0.37 ¹	0.28 ²	0.25 ²	+	0.39 ¹	0.21 ¹
PWV	0.68 ¹	0.34 ¹	0.32 ¹	0.20	-0.42 ¹	+	0.17 ²
Poikilocytosis	0.69 ¹	0.19 ²	0.16 ²	0.31 ²	-0.21 ¹	0.16 ²	+

Notes:¹ – $p < 0.05$; ² – $p > 0.05$; ³ – $p < 0.001$.

Thus, the most pronounced associations are established between HU and poikilocytosis, endothelial dysfunction and increased arterial wall stiffness.

In order to assess the relative risks of ED, left ventricular systolic dysfunction, excessive increase in arterial wall stiffness and poikilocytosis, as well as the occurrence of AH in the presence of HU in

Group 2, the risk ratio (RR) was calculated in relation to Group 1 after 6 months (Table 3).

Based on obtained results, a significant association (greater than 3.0) was found between HU and PWV (5.97), Tei Index (5.39), EDVD (4.48), AH (4.62) ($p < 0.05$). Poikilocytosis has a relatively lower (3.62), but also a significant

probability of association with HU in AH. The presence of HU in normotensive patients is associated with the occurrence of AH (a steady exceedence of SBP > 139 mm Hg and DBP > 89 mm Hg) over a six-month observation period with RR 4.62.

Table 3 – Calculation of relative risks in normotensive patients with hyperuricemia

Indicator	Relative risk	Sensitivity	Specificity	R-level
PWV	5.97	0.867	0.684	$p < 0.05$
EDVD	4.48	0.858	0.672	$p < 0.05$
Tei Index	5.39	0.800	0.563	$p < 0.05$
Poikilocytosis	3.62	0.721	0.623	$p < 0.05$
AH	4.62	0.889	0.397	$p < 0.05$

To evaluate the results of treatment in Group 2 after the course of IVLT, an analysis of DBPM indicators was performed. On the background of a decrease in the level of HU by 14.7%, a decrease in the average daily blood pressure indicators was

revealed: SBPd – by 9.0%, DBPd-by 14.4%, TI DBPd by 7.3%, PWV decreased by 20.5%, Tei Index by 12.2%, poikilocytosis by 4.7% and EDVD increase by 6.6% (Table 4).

Table 4 – Comparison of the studied parameters in Group 2 patients before and after the course of ILT

Indicator, unit	Group II (n = 52)		
	Before treatment	After treatment	$\Delta_2\%$
SBPd, mm Hg	132.3 \pm 6.36	120.4 \pm 5.251	-9.0
DBPd, mm Hg	86.5 \pm 4.65	74.1 \pm 5.20 ¹	-14.4
SBPn, mm Hg	116.3 \pm 5.32	114.7 \pm 4.48 ²	-1.4
DBPn, mm Hg	76.1 \pm 3.24	74.5 \pm 4.73 ²	- 2.1
TI SBPd, %	12.8 \pm 4.35	8.6 \pm 4.28 ²	-7.3
TI DBPd, %	17.5 \pm 5.34	10.2 \pm 4.52 ¹	-7.3
TI SBPn, %	8.4 \pm 3.48	8.8 \pm 7.67 ²	0.4
TI DBPn, %	7.1 \pm 0.89	7.0 \pm 0.95	-0.1
RMR SBP, mm Hg/h	5.4 \pm 2.28	4.8 \pm 2.29 ²	-11.1
RMR DBP, mm Hg/h	4.8 \pm 1.68	3.2 \pm 1.27 ²	-33.3
EMBPS SBP, mm Hg	18.6 \pm 4.21	19.2 \pm 3.42 ²	3.23
EMBPS DBP, mm Hg	14.1 \pm 2.38	12.4 \pm 2.63 ²	-12.1
PWV, m/s	7.8 \pm 0.94	6.2 \pm 0.71 ¹	-20.5
EDVD, %	12.1 \pm 1.13	18.7 \pm 1.42 ¹	6.6
Tei Index	0.41 \pm 0.021	0.36 \pm 0.018 ¹	-12.2
Poikilocytosis, %	12.9 \pm 1.254	8.2 \pm 1.310 ¹	-4.7
UA, μ mol/l	457.3 \pm 12.54	390 \pm 19.34 ¹	-14.7

Notes:

¹ – reliability of differences in comparison with the indicator before treatment ($p < 0.05$);

² – reliability of differences in comparison with the indicator before treatment ($p < 0.05$);

$\Delta\%$ – difference between indicators before and after treatment

To identify the effect of IVLT on the course of AH in hypertensive patients, the dynamics of DBPM indicators in Group 3A patients receiving

standard antihypertensive therapy, and Group 3B using standard antihypertensive therapy in combination with a course of IVLT, was compared.

When assessing the dynamics of indicators of daytime and nighttime blood pressure in the group, a decrease in SBPd by 7.9%, DBPd by 8.3%, and DBPn by 12.4% was revealed. It should be noted that when assessing the blood pressure load in the daytime and at night, a statistically significant ($p < 0.05$) decrease in time index (TI) blood pressure during the day is noticed. After treatment, Group 3A patients had a decrease in the morning rise of SBP (rate of morning rise (RMR) SBP by 26.1% and magnitude of the early morning blood pressure surge (EMBPS) SBP by 18.8%), but no significant reduction in these parameters of DBP was detected. It should be noted that the treatment, performed in Group 3A, was associated with a decrease in aortic

stiffness (a decrease in PWV by 7.8%) and a decrease in poikilocytosis by 0.8%.

In Group 3B, a statistically significant decrease in SBPd by 12.1%, DBPd by 10.7%, and DBPn by 14.9% was found after combination treatment with AHT and IVLT. In contrast to Group 3A, combination treatment in Group 3B was associated with a decrease in all DBPM indicators, which were responsible for the BP loading, the rate and value of its morning rise ($p < 0.05$). After the course of treatment in Group 3B, there was a decrease in PWV by 11.9%, EDVD by 1.8%, Tei Index by 9.3%, uric acid level by 6.7%, and poikilocytosis by 3.7% (Table 5).

Table 5 – Comparative characteristics of indicators in patients with arterial hypertension before and after treatment

Indicator, unit	Studied groups					
	Group 3A (n = 24)			Group 3B (n = 24)		
	Before treatment	After treatment	$\Delta_{3A}\%$	Before treatment	After treatment	$\Delta_{3B}\%$
SBPd, mm Hg	150.3 ± 6.12	138.5 ± 5.08 ¹	-7.9	152.4 ± 7.21	134.0 ± 5.11 ¹	-12.1
DBPd, mm Hg	96.1 ± 6.02	88.1 ± 4.20 ¹	-8.3	94.2 ± 5.21	84.1 ± 4.12 ¹	-10.7
SBPn, mm Hg	122.0 ± 6.29	120.2 ± 7.32 ²	-1.5	121.2 ± 5.47	110.2 ± 5.32 ²	-9.1
DBPn, mm Hg	82.2 ± 6.37	72.0 ± 5.02 ¹	-12.4	80.4 ± 5.25	68.4 ± 4.09 ¹	-14.9
TI SBPd, %	50.4 ± 3.65	26.4 ± 3.81 ¹	-24.0	48.3 ± 4.41	19.2 ± 1.82 ¹	-29.1
TI DBPd, %	42.0 ± 3.91	32.3 ± 3.82 ¹	-9.7	40.4 ± 3.41	28.3 ± 3.14 ¹	-12.1
TI SBPn, %	53.4 ± 4.10	38.4 ± 3.44 ¹	-15.0	52.1 ± 1.63	18.1 ± 3.81 ¹	-34.0
TI DBPn, %	39.5 ± 2.72	27.6 ± 3.30 ¹	11.9	37.2 ± 2.91	25.1 ± 2.44 ¹	-12.1
RMR SBP, mm Hg/h	23.0 ± 2.90	17.1 ± 1.61 ¹	-25.7	21.5 ± 3.22	8.7 ± 1.91 ¹	-59.5
RMR DBP, mm Hg/h	14.2 ± 2.31	12.2 ± 1.43 ²	-14.1	13.1 ± 2.11	7.2 ± 1.80 ¹	-45.1
EMBPS SBP, mm Hg	48.3 ± 4.14	39.2 ± 3.44 ¹	-18.8	49.1 ± 4.32	31.4 ± 3.32 ¹	-36.1
EMBPS DBP, mm Hg	27.5 ± 2.24	25.2 ± 2.10 ²	-8.4	29.2 ± 2.44	23.0 ± 2.23 ¹	-21.2
PWV, m/s	11.5 ± 0.82	10.6 ± 0.71 ¹	-7.8	11.8 ± 0.81	10.4 ± 0.71 ¹	-11.9
EDVD, %	9.4 ± 1.12	9.8 ± 0.91 ²	0.4	9.2 ± 0.62	11.0 ± 0.51 ¹	1.8
Tei index	0.42 ± 0.040	0.40 ± 0.041 ²	-4.8	0.43 ± 0.022	0.39 ± 0.024 ¹	-9.3
UA, $\mu\text{mol/l}$	364.4 ± 13.71	351.24 ± 11.26 ²	-3.6	365.8 ± 12.20	341.2 ± 11.27 ¹	-6.7
Poikilocytosis, %	17.7 ± 2.21	16.9 ± 2.11 ²	-0.8	18.8 ± 1.62	15.1 ± 1.32 ¹	-3.7

Notes:

¹ – reliability of differences in comparison with the indicator before treatment ($p < 0.05$);

² – reliability of differences in comparison with the indicator before treatment ($p < 0.05$);

$\Delta\%$ – difference between indicators before and after treatment

In Group 4A after treatment, a significant decrease of SBPd by 4.5%, DBPd by 7.3%, DBPn by 15.2% was revealed, the corresponding dynamics was observed in the TI BP, EMBPS and RMR BP indicators ($p < 0.05$). When studying the dynamics of similar indicators of patients with HU and AH who received AHT, a statistically significant decrease in PWV by 8.5%, uric acid by

6.8%, Tei Index by 10.5% and an increase in EDVD by 5.0% was found.

The dynamics of DBPM indicators after treatment in Group 4B indicates a statistically significant ($p < 0.05$) decrease in SBP and DBP indicators at the daytime and nighttime. The use of a combination of AHT and IVLT is associated with a decrease in PWV by 21.9%, Tei index by 29.3%,

uric acid level by 19.2%, poikilocytosis by 7.3% and an increase in EDVD by 8.5%, (Table 6).

Discussion of the results

The established correlations confirm the status of HU as an independent AH risk factor, both in normotensive patients and in patients with AH. In addition, the existence of statistically reliable direct

correlations between the BP level and PWV, Tei Index, poikilocytosis and inverse correlations with EDVD indicates that excessive increase in arterial wall stiffness, myocardial dysfunction and endothelial dysfunction are significant risk factors of AH.

Table 6 – Comparative characteristics of indicators in patients with arterial hypertension in combination with hyperuricemia before and after treatment

Indicator, unit	Studied groups					
	Group 4A (n = 24)			Group 4B (n = 28)		
	Before treatment	After treatment	$\Delta_{4A}\%$	Before treatment	After treatment	$\Delta_{4B}\%$
SBPd, mm Hg	153.2 ± 5.47	146.2 ± 6.04 ¹	-4.6	151.3 ± 6.07	130.4 ± 4.27 ¹	-13.9
DBPd, mm Hg	95.3 ± 5.02	88.1 ± 4.42 ²	-7.6	97.2 ± 6.29	82.6 ± 5.10 ¹	-15.0
SBPd, mm Hg	140.2 ± 4.41	132.2 ± 5.32 ²	-5.7	142.5 ± 4.64	118.0 ± 3.21 ¹	-17.2
DBPn, mm Hg	92.3 ± 2.03	78.2 ± 4.37 ¹	-15.2	90.4 ± 3.27	74.2 ± 3.33 ¹	-17.9
TI SBPd, %	45.4 ± 5.01	30.3 ± 3.21 ¹	-15.1	47.5 ± 4.38	13.6 ± 2.21 ¹	-33.9
TI DBPd, %	38.3 ± 4.32	29.3 ± 2.24 ¹	-9.0	40.1 ± 4.27	12.2 ± 2.17 ¹	-27.9
TI SBPn, %	46.3 ± 5.25	31.2 ± 4.47 ¹	-15.1	43.0 ± 4.31	26.1 ± 2.33 ¹	-16.9
TI DBPn, %	36.4 ± 4.27	24.2 ± 2.37 ¹	-12.2	39.7 ± 3.37	18.8 ± 2.44 ¹	-20.9
RMR SBP, mm Hg/h	28.4 ± 4.27	23.4 ± 2.29 ¹	-17.6	25.6 ± 3.54	14.5 ± 2.31 ¹	-43.4
RMR DBP, mm Hg/h	18.1 ± 3.35	13.4 ± 2 ¹	-26.0	18.0 ± 4.09	8.2 ± 1.11 ¹	-54.5
EMBPS SBP, mm Hg	56.2 ± 8.04	42.2 ± 4.07 ¹	-25.0	54.2 ± 5.32	36.2 ± 4.14 ¹	-33.2
EMBPS DBP, mm Hg	32.4 ± 6.16	25.7 ± 4.51 ¹	20.1	34.1 ± 5.21	25.2 ± 2.37 ¹	-26.1
PWV, m/s	13.0 ± 0.9	11.9 ± 0.7 ²	-8.5	13.2 ± 0.8	10.3 ± 0.6 ¹	-21.9
EDVD, %	8.5 ± 0.9	13.5 ± 1.4 ¹	5.0	8.7 ± 0.9	17.2 ± 1.5 ¹	8.5
Tei Index	0.57 ± 0.043	0.51 ± 0.051 ¹	-10.5	0.58 ± 0.042	0.41 ± 0.032 ¹	-29.3
UA, $\mu\text{mol/l}$	497.4 ± 15.38	459.6 ± 11.49	-7.6	499.1 ± 16.11	403.2 ± 17.41	-19.2
Poikilocytosis, %	23.8 ± 4.21	22.2 ± 4.82 ²	-1.6	24.4 ± 2.81	17.1 ± 2.72 ¹	-7.3

Notes:

1 – reliability of differences compared to the indicator before treatment ($p < 0.05$);

2 – reliability of differences compared to the indicator before treatment ($p > 0.05$);

$\Delta\%$ – difference between indicators before and after treatment

Since the calculation of relative risks demonstrates the presence of an association between HU and other AH risk factors, namely myocardial dysfunction (RR 5.39), excessive aortic wall stiffness (RR 5.97), ED (RR 4.48), it can be assumed that HU has common pathogenetic mechanisms with these factors. Moreover, the presence of HU in normotensive patients is associated with the occurrence of AH (a steady exceedence of SBP > 139 mm Hg and DBP > 89 mm Hg) over a six-month observation period ($p < 0.05$).

The use of intravenous laser therapy in combination with antihypertensive therapy allows to achieve a more significant reduction in SBPd by

4.2%, DBPd by 2.4%, DBPn by 2.5%, TI SBPd by 5.1%, TI DBPd by 2.7%, TI SBPn by 19%, RMR SBP by 33.8%, RMR DBP by 31%, EMBPS SBP by 17.3%, EMBPS DBP by 12.8%, PWV by 4.1%, endothelial dysfunction by 1.4%, systolic dysfunction by 4.5%, poikilocytosis by 2.9%, uric acid level by 3.1% in patients with hypertension ($p < 0.05$). In AH and HU comorbidity, addition of IVLT to AHT allows to achieve an additional reduction in SBPd by 9.3%, DBPd by 7.4%, SBPn by 11.5%, DBPn by 2.7%, TI SBPd by 18.8%, TI DBPd by 18.9%, TI SBPn by 1.8%, TI DBPn by 8.7%, RMR SBP by 25.8%, RMR DBP by 28.5%, EMBPS SBP by 8.2%, EMBPS DBP by 6.0%, PWV by 13.4%, endothelial dysfunction by 3.5%,

systolic dysfunction by 18.8%, poikilocytosis by 5.7%, uric acid level by 11.6% compared to monotherapy with antihypertensive drugs. In patients with normal blood pressure and hyperuricemia, the use of intravenous laser therapy

can reduce indexes of DBPM, EDVD, poikilocytosis, and the UA level ($p < 0.05$) indicators without the use of uricodepressive therapy.

Conclusions

The use of intravenous laser therapy in normotensive patients with HU is an effective method of correcting uric acid levels, endothelial dysfunction and poikilocytosis.

The use of intravenous laser therapy in combination with antihypertensive therapy allows

to achieve a statistically significant ($p < 0.05$) reduction in blood pressure, uric acid levels, excessive arterial wall stiffness, myocardial dysfunction, endothelial dysfunction and poikilocytosis in patients with stage I AH, 1-2 degrees.

Prospects for future research

A promising direction of research development is to establish the duration of the therapeutic effect of intravenous laser therapy in patients with arterial hypertension.

Conflict of interest

The authors declare no conflict of interest.

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