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## Ultrasound examination of the upper extremity vessels in the early diagnosis of peripheral angiodystonic syndrome of occupational etiology

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**Introduction.** The cardiovascular system reacts to almost all occupational hazards. Various methods for diagnostics, in particular ultrasound, may help to identify preclinical forms of the disease.

**The study aims** to development of criteria for early diagnosis of occupational diseases of the vessels of the upper extremities in machine-building workers.

**Materials and methods.** One hundred twenty-six workers of a machine-building plant were examined using standard clinical and laboratory methods, ultrasound examination of the vessels of the upper extremities and X-ray examination of the hands.

**Results.** Laboring job, hand-arm and whole-body vibration, and noise with an average work experience of 21 years are risk factors for spastic changes in the vessels of the upper extremities in workers of machine-building production. X-ray changes in the hands are determined in 83% of cases and manifest themselves as a violation of local blood circulation, cystic restructuring in the bones of the wrists, and peri-articular osteopenia. Characteristic signs of vascular pathology detected by ultrasound are an increase in the resistance index with the preservation of speed indices (in 100%), impaired venous outflow (in 82%), and pathological tortuosity of blood vessels (in 76%).

**Limitations.** We did not standardize workers depending on tobacco smoking due to the low number of workers in certain occupations.

**Conclusion.** The results of ultrasound examination of the main vessels of the upper extremities in power engineering workers showed the presence of spastic vascular changes, which, with further exposure to occupational hazards, develop into angiodystonic syndrome, which is one of the syndromes of effects of vibration or polyneuropathy.

**Keywords:** ultrasound procedure; upper limb arteries; spastic changes; index of resistance; vascular tone

**Compliance with ethical standards:** the Local ethics committee of North-West Public Health Research Center approved this study (minutes of the meeting No. 23. I from 28.10.2020).

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## Ультразвуковое исследование сосудов верхних конечностей при ранней диагностике периферического ангиодистонического синдрома профессиональной этиологии

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**Введение.** Сердечно-сосудистая система реагирует практически на все вредные производственные факторы. Различные методы диагностики, в частности ультразвуковое исследование, позволяют выявить доклинические формы заболевания.

**Цель исследования** – разработка критериев ранней диагностики профессиональной патологии сосудов верхних конечностей у работников машиностроительного производства.

**Материалы и методы.** Обследованы 126 рабочих машиностроительного завода с применением стандартных клинико-лабораторных методов, ультразвукового исследования сосудов верхних конечностей и рентгенологического исследования кистей.

**Результаты.** Тяжесть трудового процесса, общая и локальная вибрация, а также шум при среднем стаже работы 21 год являются факторами риска развития спастических изменений сосудов верхних конечностей у рабочих машиностроительного производства. Рентгенологические изменения в руках определяются в 83% случаев и проявляются нарушением местного кровообращения, кистовидными перестройками в костях

запястий и околоуставной остеопенией. Характерными признаками сосудистой патологии, выявляемой при ультразвуковой диагностике, являются повышение индекса резистентности при сохранении скоростных показателей (в 100% случаев), нарушение венозного оттока (в 82% случаев) и патологическая извитость сосудов (в 76% случаев).

**Ограничения исследования.** В связи с малой численностью работников некоторых профессий стандартизация работников в зависимости от статуса табакокурения не проводилась.

**Заключение.** Результаты ультразвукового исследования магистральных сосудов верхних конечностей у работников энергетического машиностроения показали наличие спастических сосудистых изменений, которые при дальнейшем воздействии вредных производственных факторов перерастают в ангиодистонический синдром, являющийся одним из синдромов вибрационной болезни или полиневропатии.

**Ключевые слова:** ультразвуковое исследование; артерии верхних конечностей; спастические изменения; индекс резистентности; сосудистый тонус

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**Конфликт интересов.** Авторы декларируют отсутствие явных и потенциальных конфликтов интересов в связи с публикацией данной статьи.

**Финансирование.** Исследование не имело спонсорской поддержки.

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## Introduction

Saving the health of working population is a priority direction of the state policy in the field of labor relations and ensuring healthy and safe working conditions by the employer, prevention of occupational diseases, since the economic recovery of the state is directly related to the able-bodied population [1].

In modern conditions, an important problem is the growth of non-communicable morbidity [2]. Detection of diseases associated with exposure to occupational hazards at an early stage and their timely prevention allows to reduce the disability of workers and increase the period of active labor activity.

Diseases associated with the influence of physical factors are leading in the structure of occupational pathology, effects of vibration occupy the second place in this group and is registered in almost 30% of cases, second only to noise effects on inner ear [3].

The most unfavorable working conditions are observed at a number of enterprises engaged in mining, metallurgy, shipbuilding and mechanical engineering [4]. A significant place in the clinical picture of employees of these industries is occupied by changes in the cardiovascular system in the form of hypertensive diseases, tachycardia and other cardiac arrhythmias [5]. The mechanism of spastic changes in arteries and angiodystonic syndrome of the upper extremities is associated with dysfunction of ergotropic and trophotropic suprasegmentally and segmental vegetative structures [6, 7].

Spastic vascular changes precede peripheral angiodystonic syndrome, which is part of effects of vibration and accompanies polyneuropathy from functional overstrain [8]. Often, changes are detected already at the stage of angiodystonic vascular reaction, when workers cannot work in their former specialty and are forced to undergo a long period of treatment and rehabilitation [9]. Therefore, early detection of vascular changes (preclinical form) and timely prevention contribute to preventing the development of occupational diseases and prolonging the active labor activity of the employee [10]. To the least extent, this occupational pathology is described in workers of machine-building production.

**The aim of the study** was to develop criteria for the early diagnosis of occupational diseases of the vessels of the upper extremities in workers of machine-building production.

## Materials and methods

In the course of the study, 126 employees (13 women and 113 men) of one of the large modern machine-building enterprises of St. Petersburg were examined. Data on the state of health of

patients were obtained during an in-depth clinical and instrumental examination on the basis Public Health Research Center in February 2021.

To describe the working conditions according to the severity of labor process (heavy physical work), hand-arm and whole-body vibration, which determine the increased risk to health in terms of peripheral vascular disorders we used data of a special assessment of working conditions conducted at the workplace of the enterprise in 2017–2019.

Workers underwent routine medical check-up by doctors (general practitioner, surgeon, neurologist, ophthalmologist, ear-nose-throat specialist, and occupational physician), standard laboratory tests, X-ray examination of the hands, triplex ultrasound scanning of the main vessels of upper extremities.

X-ray examination of hands was carried out on a radiographic device “UNISCAN” (“PULMOSCAN-760U”) in an anterior-posterior projection, field size 22×22 sq.cm, focal length 138 cm, tube voltage 70 kV, with an exposure of 40/4.7 mA/sec and an effective radiation dose of the patient 0.0025 mSv.

Ultrasound scanning of upper extremities arteries (brachial, elbow and radial) was carried out on a device of the expert class Samsung Medison HS50-rus with a linear sensor at an operating frequency of 5–15 MHz, at a depth of up to 1.5–2.0 cm according to the developed technique [11]. The following velocity and spectral parameters of vascular blood flow were measured systolic (pulse) blood flow rate and resistance index (RI, index Purselo). The presence or absence of stenoses, occlusions, and aneurysms were assessed, and sites with abnormal blood flow were searched.

To study the vascular bed of the main arteries of the upper extremities, a reference group of 80 practically healthy volunteers in occupations without physical exertion or with moderate physical exertion was normally examined: teachers, kindergarten teachers, teachers of higher educational institutions, catering workers whose working conditions were assessed as acceptable. The distribution by gender and age was comparable with the main group.

Statistical processing of the research results was carried out on IBM SPSS Statistics v.22 and Microsoft Office Excel 2010 software. The normality of the distribution in the samples that included blood flow indicators (systolic blood flow rate, RI) in the studied arteries was determined using the Kolmogorov–Smirnov criterion, and in the group of women by using the Shapiro–Wilk criterion. In the case of a normal distribution in the samples, the T-criterion for independent samples was used, adjusted for Levin’s criterion of equality of variances. With a distribution different from normal, the Mann–Whitney criterion was used. The age of patients is presented in the format  $M \pm m$  (arithmetic

Table 1 / Таблица 1

**Characteristics of working conditions at workplaces of the enterprise****Характеристика условий труда на рабочих местах предприятия**

Occupation Профессия	Number of workers Число работников <i>n</i> = 126	Labor process severity	Whole-body vibration	Hand-arm vibration	Noise
		Тяжесть трудового процесса	Общая вибрация	Локальная вибрация	Шум
class of working conditions / класс условий труда					
Boilermaker / Котельщик	15	3.1	2	3.1	3.2
Electric and gas welder / Электрогазосварщик	13	3.1	2	2	3.1
Metal work assembler Слесарь по сборке металлоконструкций	28	3.1	2	3.1	3.1
Metal Cleaner / Чистильщик металла	7	2	2	3.1	3.3
Overhead crane operator Машинист мостового крана	13	3.1	3.1	2	3.2
Manual Cutting Gas Cutter Газорезчик ручной резки	11	3.1	2	2	3.2
Chopper / Обрубщик	4	3.1	2	3.1	3.2
Polisher / Полировщик	8	3.2	2	2	3.1
Slinger / Стropальщик	4	3.1	2	2	3.2
Metal Cutter / Резчик металла	7	3.1	2	3.1	3.2
The charge maker / Шихтовщик	9	3.1	2	2	3.2
Grinder / Шлифовщик	7	2	2	3.1	3.1

mean and standard error of the mean), the resistance index and blood flow rate were Me [Q<sub>1</sub>–Q<sub>3</sub>] (median and interquartile range). The critical significance level of the null hypothesis was assumed to be 0.05 [12].

**Results**

Because of the conducted studies, it was found that the average age of patients was 48.1 ± 1.1 years. The work experience under the influence of occupational hazards that could cause occupational disease was 21.0 ± 1.1 years. The distribution of patients depending on the occupation and classes of working conditions for occupational hazards is presented in Table 1.

As can be seen from the presented table, the final class of working conditions at all analyzed workplaces is not lower than 3.1 (harmful working conditions of the 1<sup>st</sup> degree). The most unfavorable working conditions (harmful working conditions

of the 3<sup>rd</sup> degree) were observed in a metal cleaner. The leading occupational hazards in almost all workplaces were increased noise levels, the severity of the labor process (heavy physical work) and hand-arm vibration.

The main occupations in this manufacture, where hand-arm vibration and heavy physical work were recorded, were boilermakers, metalwork assemblers, metal cutters and choppers. They accounted for 43% of all surveyed workers. 46% of employees in occupations of an electric and gas welder, an overhead crane operator, a hand-cut gas cutter, a polisher, a slinger, a charge maker had excess hygienic standards for noise and the severity of the labor process.

Result of the clinical examination revealed that the main complaints were pain in hands (22 people) and chilly hands (5 people), which was an indirect sign of microcirculation disorders (Table 2). Objective neurological examination did not determine any pathological changes that are special for vascular pathology.

Table 2 / Таблица 2

**Physical examination findings****Данные объективного осмотра**

Occupation Профессия	Number of workers Число работников <i>n</i> = 126	Complaints / Жалобы			
		pain in hands / боль в руках		chilliness in hands / зябкость кистей	
		<i>n</i>	%	<i>n</i>	%
Boilermaker / Котельщик	15	2	13.3	–	–
Electric and gas welder / Электрогазосварщик	13	4	14.3	2	7.1
Metal work assembler / Слесарь по сборке металлоконструкций	28	2	28.6	1	14.3
Metal Cleaner / Чистильщик металла	7	3	75.0	3	75.0
Overhead crane operator / Машинист мостового крана	13	1	14.3	–	–
Manual Cutting Gas Cutter / Газорезчик ручной резки	11	–	–	–	–
Chopper / Обрубщик	4	–	–	–	–
Polisher / Полировщик	8	–	–	–	–
Slinger / Стropальщик	4	–	–	–	–
Metal Cutter / Резчик металла	7	–	–	–	–
The charge maker / Шихтовщик	9	–	–	–	–
Grinder / Шлифовщик	7	2	28.6	2	28.6

Table 3 / Таблица 3

## Findings of X-ray examination of the hands

Данные рентгенологического обследования кистей рук

Occupation Профессия	Number of workers Число работников <i>n</i> = 126	Peri-articular osteopenia Околосуставная остеопения		Deforming osteoarthritis Деформирующий остеоартрит		Cyst-like clearances in wrist bones Мелкие кисты в костях запястья	
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Boilermaker / Котельщик	15	8	53.3	5	33.3	5	33.3
Electric and gas welder Электрогазосварщик	13	2	15.4	6	46.2	9	69.2
Metal work assembler Слесарь по сборке металлоконструкций	28	21	75.0	10	35.7	11	39.3
Metal Cleaner / Чистильщик металла	7	5	71.4	2	28.6	3	42.9
Overhead crane operator Машинист мостового крана	13	1	7.7	5	38.5	1	7.7
Manual Cutting Gas Cutter Газорезчик ручной резки	11	2	18.2	2	18.2	—	—
Chopper / Обрубщик	4	4	100.0	3	75.0	2	50.0
Polisher / Полировщик	8	5	62.5	7	87.5	3	37.5
Slinger / Стропальщик	4	—	—	1	25.0	2	50.0
Metal Cutter / Резчик металла	7	4	57.1	4	57.1	4	57.1
The charge maker / Шихтовщик	9	7	77.8	5	55.6	5	55.6
Grinder / Шлифовщик	7	4	57.1	6	85.7	2	28.6

As can be seen from the table presented, complaints were registered mainly in occupations (a chopper, a grinder, a metal cleaner, a metal cutter, a metalwork assembler, a boilermaker), where the most harmful working conditions were recorded (in 82%).

The results of laboratory blood tests showed hypercholesterolemia in 32% of metalwork assemblers and in 27% of electric and gas welders.

According to the results of hands X-ray examination, changes were detected in 83% of the examined and manifested in the form of periarticular osteopenia in 70%, cyst-like clearances in the navicular and cephalic bones in 40%; deforming osteoarthritis of the interphalangeal, metacarpophalangeal, wrist joints and wrist bone joints on both sides in 44% (Table 3).

From the data presented, it can be seen that radiological changes were more often determined in occupations of a metalwork fitter (33%), a boiler maker (14%), an electric and gas welder (13%), a polisher (11%).

Ultrasound examination of the upper extremities main arteries did not reveal hemodynamic significant stenoses,

occlusions and aneurysms of the forearm arteries, the diameter of the examined arteries was recorded within the normal range. Atherosclerotic plaques, thrombosis along the vessels of the forearms were not detected. There was venous dyscirculation in the veins of the forearm, the failure of the valvular apparatus in 103 people, the initial S-shaped and C-shaped tortuosity of the radial and ulnar arteries was greater in the distal third in 96 people. The results of ultrasound examination of the arteries in the main group and in the referent group are presented in Table 4.

Comparative analysis of blood flow parameters in women and men showed no statistically significant differences ( $p > 0.05$ ), and therefore further analysis was carried out without standardization of workers by gender. As can be seen from the presented table, statistically significant differences were found between the values of the RI for all the analyzed arteries and the norm values on both the right and left arm ( $p < 0.001$ ). There were no statistically significant differences between the blood flow rate in the examined arteries ( $p > 0.05$ ).

Table 4 / Таблица 4

## The results of ultrasound examination of the main arteries of the upper limbs

Результаты ультразвукового исследования магистральных артерий верхних конечностей

Arteries Артерии	Blood flow rate (V), cm/sec Скорость кровотока (V), см/с			Resistance index (RI) Индекс резистентности (RI)		
	main group основная группа <i>n</i> = 126	reference group группа сравнения <i>n</i> = 237	<i>p</i> *	main group основная группа <i>n</i> = 126**	reference group группа сравнения <i>n</i> = 237	<i>p</i> *
Left ulnar / Левая локтевая	48.0 [42.6–64.2]	54.3 [50.2–59.7]	0.054	1.00	0.77 [0.70–0.92]	< 0.001
Right ulnar / Правая локтевая	53.2 [50.6–55.8]	54.6 [50.7–59.1]	0.601	1.00	0.77 [0.72–0.90]	< 0.001
Left radial / Левая лучевая	54.5 [51.8–57.2]	55.2 [53.6–64.1]	0.466	1.00	0.75 [0.69–0.83]	< 0.001
Right radial / Правая лучевая	57.6 [55.0–60.1]	55.8 [53.2–64.5]	0.115	1.00	0.75 [0.68–0.87]	< 0.001
Left brachial / Левая плечевая	73.3 [70.5–76.0]	71.1 [65.8–75.1]	0.257	1.00	0.79 [0.70–0.94]	< 0.001
Right brachial / Правая плечевая	72.2 [69.4–75.1]	72.4 [65.2–76.7]	0.834	1.00	0.80 [0.71–0.93]	< 0.001

Note: \* *p* – is the exact significance of the differences (Mann–Whitney criterion); \*\* – for the main group, the first and third quartiles of the resistance index are not shown due to their coincidence with the median.

Примечание. \* *p* – точная значимость различий (критерий Манна–Уитни); \*\* – для основной группы первый и третий квартили индекса резистентности не показаны из-за их совпадения с медианой.

Further analysis in occupations with heavy physical work and hand-arm vibration (boilermaker, metalwork assembler, chopper, metal cutter) and occupations with heavy physical work and noise (electric and gas welder, overhead crane operator, manual welding gas cutter, polisher, slinger, charge) showed no statistically significant differences in speed blood flow and resistance index in the examined arteries ( $p > 0.05$ ).

## Discussion

The conducted study of power engineering workers showed that the average age of the surveyed was 48 years, and the average work experience under the influence of harmful production factors was more than 20 years. About 43% of employees are boilermakers, metalwork assemblers, metal cutters and choppers, at whose workplaces excess hand-arm vibration, heavy physical work were recorded. 46% of employees in occupations of an electric and gas welder, overhead crane operator, a hand-cut gas cutter, a polisher, a slinger, a charge maker had noise and heavy physical work.

It is noteworthy that a quarter of the employees complained about the pathology of the upper extremities, while an objective examination by a neurologist revealed no pathological changes. The results of laboratory blood tests revealed hypercholesterolemia in 32% of metalwork assemblers and 27% in electric and gas welders, which, apparently, can be explained by the predominance of workers over 45 years old in these occupations. As is known, the prevalence of lipid metabolism disorders doubles with age [13].

Hands X-ray examination showed changes in 83% of the examined workers in the form of cyst-like rearrangement in wrists bones (40% of patients) and periarticular osteopenia in 70%. This X-ray picture is specific to local circulatory disorders [14].

As is known from the literature data, peripheral angiodystonic syndrome can develop due to physical overstrain and (or) exposure to vibration exceeding the remote control, and manifest as angiospasm [14, 15].

The results of earlier ultrasound examinations of the upper extremities main arteries in patients with an established occupation disease showed that the first stage of hand-arm vibration syndrome is characterized by changes in the form of a decrease in the pulse rate of blood flow through the ulnar artery

and a moderate increase in peripheral resistance (pulsation index and resistance index) in the radial and ulnar arteries. These changes are symmetrical on both upper limbs [16].

With physical overstrain of upper extremities against the background of an increase in peripheral blood flow resistance indices, an increase in blood flow velocity along the ulnar artery is noted, no changes are detected along the radial artery [16].

The results of ultrasound examination of the main arteries of the upper extremities in workers presented in this investigation differ from those described above in that the velocity indicators of blood flow are preserved ( $p < 0.001$ ), while the resistance index is increased ( $p > 0.05$ ). These changes speak in favor of vascular tone disorders in the form of spastic changes preceding peripheral angiodystonic syndrome [17, 18].

Disturbance of venous outflow in the form of venous discirculation through the veins of the forearm was determined in 82% of cases, initial changes in the anatomical course of the ulnar and radial arteries in the form of pathological tortuosity in 76%.

## Conclusions

The features of working conditions that determine the formation of spastic changes in vessels of upper extremities in machine-building workers are heavy physical work is not less than class 3.1 with an average work experience of 21 years. At the same time, the main occupational hazards include hand-arm and whole-body vibration, heavy physical work, noise. Radiological changes in hands are detected in 83% of the examined workers and manifest themselves in the form of local circulatory disorders, cyst-like rearrangement in the wrist bones in 40%, in the form of periarticular osteopenia in 70%. The most informative method of early diagnosis of vascular changes in the main arteries of upper extremities is ultrasound. The characteristic signs are an increase in the resistance index with the preservation of speed indicators (recorded in 100%), a disturbance of venous outflow (in 82%), pathological vascular tortuosity (in 76%). Thus, the results of ultrasound examination of the main vessels of the upper extremities in power engineering workers showed the presence of spastic vascular changes that may develop into angiodystonic syndrome with further exposure to occupational hazards, which is one of the syndromes of effects of vibration or polyneuropathy from physical overstrain.

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