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ASSESSMENT OF CARDIOVASCULAR PATHOLOGY RISK IN MINERS EMPLOYED AT DEEP CHROME MINES

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Deep mining is widely spread in Russia; therefore, preservation of labor resources employed in the sphere is a vital task. Workers who are employed at deep chrome mines are exposed to combined effects exerted by adverse occupational factors. These factors can either be common for deep mining, or they can be related to specific natural resources. Adverse risk factors cause higher risks that not only occupational, but also production-related diseases can emerge in miners. The authors performed a complex hygienic assessment of working conditions which exist in deep chrome mines. We detected that working conditions in mines could be characterized as "hazardous" and they belonged to 3–4 hazard category due to combined negative effects exerted by physical and chemical factors of the labor process. We also performed clinical and functional examination of 135 workers employed at a chrome mine. Our focus group was made up of 88 miners; the reference group included 47 workers employed at this mine who weren't exposed to adverse factors related to chrome ores mining. All the examined workers were males, aged 30–49, with their working experience ranging from 10 to 25 years. We revealed a failure in functional activity of the endothelium in half of miners whose working experience was shorter than 10 years; and relative risk of such failure was almost 8 times higher than for workers who didn't deal with deep chrome mining. 10 % miners who had been working at the mine for more than 10 years had a substantial decrease in functional reserves of their cardio-respiratory system. Relative risk of atherosclerotic changes in vascular walls, morphological changes in the cardiac muscle and the valve apparatus was from 3.5 to 12 times higher for miners than for workers who didn't deal with deep chrome mining. We detected a direct correlation between a decrease in functional activity of the endothelium and adaptation reserves of the cardio-respiratory system and increased chrome contents in miners' blood. Periodical medical examinations of workers should include functional and morphologic research performed on the cardiovascular system as it will help to reduce morbidity with cardiovascular-pathology among miners employed at deep chrome mines and to properly implement an overall set of preventive measures.

Key words: *risk assessment, chrome mining, production-related diseases, morphofunctional changes in the vessels, the cardiac muscle and the valve apparatus of the heart.*

Working population in the Russian Federation will go down by 3 million people by 2020 as per forecasts made by the RF Ministry for Economic Development. Given that, public healthcare faces an urgent task to develop a set of activities aimed at preserving health and long occupational life of

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employable people [1, 2, 3]. But at the same time, data obtained in multi-focus research prove that more than 40% cases of temporary disability are caused by diseases related to unsatisfactory working conditions [1, 4–8].

Mining industry is one of the most successful industrial branches in the RF and preservation of labor resources there plays a most significant role in providing high labor productivity, competitiveness, and financial stability of enterprises [9–11]. Chrome ores mining is a key activity in the branch [3, 4, 12, 13]. Chrome ores are a scarce raw material in Russia and they are usually mined underground via pinpoint explosions [12,13]. Adverse/hazardous working conditions which are characteristic for mining industry cause significant health risks for workers [1, 4, 5, 14]. Workers employed at deep chrome mines are exposed to combined effects produced by adverse occupational factors when they perform their work tasks. These adverse factors are both common for any mining (neuro-psychic stress, excessive muscular load, forced body posture, increased dustiness at a workplace, unfavorable microclimate, increased radioactive background and electromagnetic radiation, in-plant noise, vibration, etc.) and related to composition of ores that are mined [1,12–15]. As per data taken from literature, combined effects produced by occupational factors, including chemical ones, have the following negative outcomes: miners suffer from angiodystonia and microcirculation disorders together with hypercoagulation, changes occur in adhesive-aggregative properties of their thrombocytes, rheological properties and oxygen-transporting function of their blood deteriorate, circulatory hypoxia occurs, lipid peroxidation is activated, and antioxidant protection is depleted [1,9,12–14]. It was detected that long-term aerogenic exposure to chrome compounds leads to disorders in vascular tonus regulation and cardiac activity, occurrence of pathomorphologic and histochemical changes in vascular walls, dystrophy, and energetic imbalance of cardiac hystiocytes [6, 9, 12–14]. Results obtained via epidemiologic and clinical research prove that cardiovascular pathology occurs in miners at an earlier age than in population in general, and life-threatening situations and disability related to this pathology are detected among miners more frequently [9, 14]. Targeted programs for early diagnostics and prevention of these diseases are to be based on risk assessment and determination of morpho-functional pathogenetic peculiarities related to cardiovascular pathology development in miners employed at deep chrome mines. Implementation of such programs will allow to stabilize working teams and increase economic efficiency of the branch.

Our research goal was to assess risks and to determine morpho-functional peculiarities associated with cardiovascular pathology development in miners employed at deep chrome mines.

Data and methods. We performed sanitary-hygienic assessment of working conditions and clinical and functional examination of 135 workers employed at a deep chrome mine. Our focus group was made up of 88 miners (miners, drifters, drilling machine operators, timber-men, scraper winch operators, spur drillers, and mining foremen) who were exposed to synergetic influence exerted by adverse occupational factors during their work shift. The reference group included 47 workers employed at the same mine but they worked on the surface and didn't have any direct contact with adverse factors associated with chrome ore mining. All the examined workers were male. Average age of workers from the focus group was 43.7±8.5 (38.9±8.4 in the reference group, p>0,05), средний стаж работы – 19,6±6,1 лет (в группе сравнения –17,3±4,7, p>0.05). The groups were comparable as per socioeconomic status and basic lifestyle factors, such as nutrition, smoking, alcohol intake, and physical activity (p>0.05). The examination was prospective (2015–2017).

Sanitary-hygienic assessment of working conditions was based on the analysis of reports drawn as per results of special assessment of working conditions (SAWC) and data obtained via field observations over working area air in accordance with valid regulatory documents[1].

To determine fractional structure, we took

[1] R 2.2.2006-05. Guide on hygienic assessment of working area and labor process factors. Criteria and classification of working conditions / approved by the RF Chief Sanitary Inspector on July 29, 2005. *KODEKS: an electronic fund of legal and reference documentation*. Available at: http://docs.cntd.ru/document/1200040973 (access date 26.06.2018)

dust samples on AFA-VP-20-2 filters. Suspended substances were determined with gravimetric technique[2]. To measure mass chrome concentration in working area air (WAA), we took samples on AFA-HP-20 filters.

Samples were prepared for analysis via "dry" mineralization in a muffle furnace; ash that had formed there was then dissolved in nitric acid. Chrome concentration in samples was detected with atomic absorption spectrometry (Aanalyst-400 spectrophotometer, PerkinElmer, the USA) in "acetylene-air" flame as per a conventional procedure[3]. Chrome concentration in blood was detected with inductively coupled plasma mass spectrometry (ICP-MS)[4]. Chemical elements contents were measured with Agilent 7500cx mass spectrometer ("Agilent Technologies Inc.", the USA).

A priori occupational health risk for workers dealing with deep chrome mining was assessed on the basis of sanitary-hygienic assessment of working conditions in accordance with R 2.2.1766-03[5].

Our in-depth clinical examination included research on occupational routes, data taken from case histories with assessment of lifestyle factors (heredity, tobacco smoking, and physical activity), functional examination of workers from the focus and the reference group. Volumes of clinical and functional research were determined in conformity with the RF State Standard GOST-R 52379-2005 "Good Clinical Practice"[6], as well as valid documents and standards.

We performed comparative analysis of basic diseases prevalence among workers in two groups; the analysis was based on the results obtained during periodical medical examinations and in-depth clinical and functional examination. Cardiovascular pathology was among these basic diseases.

We calculated Skibinslaya Index (SI) as per the following formula:

$$SI=0.01*VCL*BH/HR,$$

where VCL is vital capacity of lungs (in ml), determined with "Schiller SP-10" spirograph; BH is breath-holding (in minutes) during a test; HR is heart rate (per minute) determined with "Schiller AT-10 plus" electrocardiograph.

We assessed vasomotor function of the brachial artery endothelium in endothelium-dependent vasodilatation test as per a modified procedure developed by D.S. Celermajer et al. (1992); we assessed the state of extracranial sections in brachiocephalic arteries as per a conventional procedure developed by J.H. Stein et al (2008). Both tests were performed with an expert ultrasound scanner "Vivid q" with a linear sensor (4.0–13.0 MHz) [6, 16]. Doppler cardiography was performed with an expert ultrasound scanner "Vivid q" with a sector phase sensor (1.5–3.5 MHz). Structural and Doppler parameters of the heart were measured as per a conventional procedure [17, 18].

The program of sanitary-hygienic and clinical-functional research was approved by the Ethics Committee of the Federal Scientific Center for Medical and Preventive Health Risk Management Technologies (minutes No. 2, 2015). Medical and

[2] Guidelines 4.1.2468-09 Measurement of mass concentrations of dust in working are air at mining and non-metallic enterprises 2005. *KODEKS: an electronic fund of legal and reference documentation*. Available at: http://docs.cntd.ru/document/898911988 (access date 26.06.2018) (in Russian).

[3] M-01V/2011. The procedure for measuring mass concentrations of metals in pollutants emissions into the atmosphere and in working area air at industrial enterprises. *MEGANORM: information system*. Available at: http://meganorm.ru/Data2/1/4293754/4293754051.htm (access date 26.06.2018) (in Russian).

[4] Determination of chemical compounds and elements in biological media: A collection of methodical guidelines MG 4.1.3056-13, 4.1.3057-13 MG 4.1.3158-4.1.3161-14 MG 4.1.3230-4.1.3233-14. *The Federal Service for Surveillance over Consumer Rights Protection and Human Well-being*. Available at: http://www.rospotrebnadzor.ru/documents/details.php?ELEMENT_ID=5616 (access date 26.06.2018) (in Russian).

MG 4.1.3230–14. How to measure mass concentrations of chemical elements in biological media (blood and urine) with inductively coupled plasma mass spectrometry. *MEGANORM: information system MEGANORM: information system*. Available at: http://meganorm.ru/Index2/1/4293757/4293757318.htm (access date 26.06.2018) (in Russian).

[5] R 2.2.1766-03. The Guide on Assessment of occupational risks for workers' health. Organizational and methodical grounds, principles, and assessment criteria. *Labor protection in Russia: information portal*. Available at: https://ohranatruda.ru/ot_biblio/norma/246225/ (access date 26.06.2018) (in Russian).

[6] GOST R 52379-2005. Good Clinical Practice: The RF national Standard. *KODEKS: an electronic fund of legal and reference documentation*. Available at: http://docs.cntd.ru/document/1200041147 (access date 26.06.2018) (in Russian).

biological research was conducted in full conformity with ethical principles fixed in Helsinki Declaration (1983). All the examined patients gave their voluntary informative consent to take part in sociological, clinical-functional, and laboratory research.

Information was analyzed with Statistica 6 software program and specific software compatible with MS-Office applications. Normalcy of measured variables distribution was checked on the basis of Kolmogorov-Smirnov test. We applied mean value (M) and error of the mean (m) to obtain quantitative characteristics of the examined parameters. Validity of discrepancies in the examined parameters between groups under comparison (Mn ± mn against Mk ± mk) was determined as per Student test ($t>2.0$; $p\leq0.05$) [19, 20].

Results and discussion. Analysis of SAWC data for the focus group revealed that equivalent noise at miners' workplaces varied from 65.3–70.9 dB(A) (miners and mining foremen, the 2nd hazard class of working conditions) to 108.2-114.9 dB(A) (drifters, spur drillers, and drilling machine operators, 3.4 hazard class of working conditions). Local vibration existing at workplaces of drifters and spur drillers was higher than the MPL (126 dB) and reached 135 dB while overall vibration was equal to 127 dB (with MPL set at 115 dB, 3.3 hazard class). Local vibration at workplaces of scraper winch operators amounted to 127 dB, and overall vibration was equal to 116 dB (3.1 hazard class). Low air temperature (9^0C, 3.3 hazard class) was detected at workplaces of all the miners. Regional/overall physical load and frequent forced (uncomfortable) body posture made for working conditions to be ranked as having 3.3 hazard class for drifters, spur drillers, and scraper winch operators; as having 3.2 hazard class, for miners, timber-men, and drilling machine operators; as having 3.1 hazard class, for mining foremen. Overall, working conditions at workplaces for all major mining occupations were considered "adverse" and were ranked as having 3.3 and 3.4 hazard class (Table 1).

Field observations results revealed that suspended substances (dust) contents in working area air for drifters, spur drillers, drilling machine operators, and scraper winch operators corresponded to 3.1 hazard class while dustiness existing at workplaces of miners, timber-men, and mining foremen didn't exceed 2 hazard class (Table 2).

At the same time, chrome concentration at workplaces of workers from the focus group didn't exceed 0.002-0.012 mg/m^3 (average shift concentration was lower than 0.5 mg/m^3; MPL is fixed at 1.0 mg/m^3), and it also corresponded to 2 hazard class (Tables 2, 3).

Chrome concentration in blood of workers from the focus group reached 0.0061±0.0022 μg/cm^3, while it was substantially lower in the reference group and didn't exceed 0.0003±0.0001 μg/cm^3 ($p=0.006$). We should note that chrome concentration in blood detected in the focus group was substantially higher than the reference level (0.0001 μg/cm^3, $p<0.001$), which can be related to cumulative effect of chrome which is typical of most metals [12].

We examined contributions made by various adverse occupational factors existing at workplaces of miners in conformity with valid regulatory documents[1], the examination revealed that a leading role belonged to physical factors of labor process (in-plant noise, vibration together with low air temperature and labor process hardness).

Table 1

Overall assessment of working conditions for workers with basic occupations in deep chrome mining

Occupations	Working conditions class as per its hazard and (or) danger							
	Chemical factor	Noise (Lequiv.)	Vibration (overall)	Vibration (local)	Microclimate	Labor Hardness	Labor Intensity	Overall estimation
miners	2	2	–	–	3,3	3,2	1	***3.3***
drifters	2	3.4	3,2	3,3	3,3	3,3	1	***3.4***
timber-men	2	3.2	–	2	3,3	3,2	1	***3.3***
spur drillers	2	3,4	3,2	3,3	3,3	3,3	1	***3.4***
mining foremen	–	2	–	–	3,3	3,1	2	***3.3***
scraper winch operators	2	3,3	3,1	3,1	3,3	3,3	1	***3.4***
drilling machine operator	2	3,4	2	2	3,3	3,2	1	***3.4***

Table 2

Filed observation results showing contents of suspended substances and chrome in working are air at workplaces of workers with basic occupations in deep chrome mining

Sampling point	Suspended substances, mg/m^3	Chrome, mg/m	Comments
Workplaces of sour drillers, drifters, scraper winch operators, and drilling machine operators	4,007 ± 0,962	< 0,0015	Measurements were performed after basic work operations had been completed (drilling, drifting, and scraping)
Miners' workplaces	2,016 ± 0,484	0,012 ± 0,003	Measurements were performed after trucks had been loaded
Timber-men's workplaces	0,704 ± 0,169	0,0034 ± 0,0008	Measurements were performed during basic work operations
Mining foremen's workplaces	0,443 ± 0,106	0,0020 ± 0,0005	Measurements were performed during basic work operations

Table 3

Assessment of working conditions class as per hazard and (or) danger related to chemical factors for workers with basic occupations in deep chrome mining

Occupations	Average shift chrome concentrations at workplaces (mg/m^3)	MPL	Overall assessment of working conditions class as per hazard and(or) danger related to chemical factors
miners	Lower than 0.5	1,0	2
drifters	Lower than 0.5	1,0	2
timber-men	Lower than 0.5	1,0	2
spur drillers	Lower than 0.5	1,0	2
mining foremen	-	1,0	1
scraper winch operators	Lower than 0.5	1,0	2
drilling machine operator	Lower than 0.5	1,0	2

Exposure to dust combined with chrome compounds is an additional adverse factor of labor process that exists at workplaces of drifters, spur drillers, drilling machine and scraper winch operators; exposure to dust and chrome compounds leads to summation of negative effects in target organs.

Working class conditions at all the workplaces in the reference group were admissible and corresponded to 2 hazard class.

We performed dynamic analysis of morbidity among workers from the examined groups and revealed that miners ran 2.8-5 times higher relative risks of nervous system diseases (ICD10: G00-G99), diseases in hearing organs (ICD10: H60-H95), upper respiratory tract diseases (J30-J84), and endocrine pathology (ICD10: E00-E07) than workers from the reference group ($p<0.001$–0,02), and diagnosed diseases were often (53-72%) or even mostly (>80%) occupational (Table 4).

Diseases of the circulatory system (ICD10: I00-I99) diagnosed in 2015-2017 in 66 workers from the focus group had a special place in morbidity structure among miners; these diseases made for their further employment strictly on the surface. They were replaced in underground operations by young workers with minimal working experience and it led to a decrease in newly detected morbid events related to the circulatory system diseases, from 28.7% in 2015 to 18.9% in 2017 ($p=0.05$). At the same time, in 2015-2016 miners with basic occupations ran 2 times higher relative risks of circulatory system diseases than workers from the reference group ($p<0.001$), and diagnosed diseases were occupational ones in 48-49% cases (average causality) (Table 4).

We analyzed the results of functional examination performed on workers from the compared groups in order to get an insight into peculiarities of cardiovascular pathology development in miners dealing with deep chrome mining. Skabinskaya Index calculation revealed that only 86.5% workers from the focus group had functional state of their cardiovascular and respiratory system at physiological level (the integral parameter was equal to 30-60 arb. units and higher) while the same level was detected in 100% of workers from the reference group ($p=0.01$); this parameter didn't exceed 21.8±2.6 arb. units in 13.5% miners ($p=0.03$ against the physiological standard), and it proved there was a significant decrease in func-

tional reserves of the cardiovascular and respiratory system.

We compared Skibinskaya Index in miners with different work experience and revealed that workers who had been employed at deep chrome mines for less than 10 years had its value lower than the physiological standard (26.3±2.8 arb. units; p=0.05) in quite insignificant number of cases (2.4%); while miners with longer work experience had this value lower than the physiological standard in each tenth case (11.1%), and the value didn't exceed 17.3±3.1 arb. units (p=0.02 against the group with working experience less than 10 years). We detected that a decrease in Skibinskaya Index value depended on chrome concentration in blood (b0=-1.89, b1=1,402.55; R^2=0.55; p≤0.001).

Table 4

Analysis of basic nosologies prevalence among workers from the compared groups

Categories of diseases (ICD10)	Observation period	Group		Relative risk of pathology for workers from focus group(p≤0,05)	CI	An extent to which a pathology detected in workers from focus group is occupational		Validity of discrepancy in frequency of pathology in the compared groups (p<0,05)
		Focus group (%)	Reference group (%)			*EF* %	Qualitative estimation	
Diseases of the nervous system (G00-G99)	2015	19,5	10,6	1,84	0,61–5,52	45	Average	**<0,001**
	2016	28,7	10,6	2,70	1,11–6,60	62	High	
	2017	54,0	14,8	3,63	1,99–6,60	72	Extremely high	
	2015–2017	34,1 ± 4,4	12,0 ± 6,0	2,72 ± 2,22	2,91–7,14	59,2 ± 33,9	-	
Diseases of the circulatory system (I00-I99)	2015	28,7	14,8	1,93	0,85–4,36	48	Average	**<0,001**
	2016	37,9	19,1	1,98	1,03–3,82	49	Average	
	2017	18,9	13,6	0,72	0,26–1,95	47	Average	
	2015–2017	28,5 ± 9,5	15,8 ± 7,2	1,54 ± 0,71	1,20–2,18	48,0 ± 2,5	Average	
Diseases of the musculoskeletal system (M00-M99)	2015	13,7	10,6	1,30	0,17–9,8	22	Insignificant	0,18
	2016	16,0	10,4	1,51	0,40–5,79	33	Average	
	2017	19,5	10,5	1,84	0,61–5,52	45	Average	
	2015–2017	16,4 ± 7,3	10,5 ± 0,3	1,55 ± 0,68	0,95–2,51	33,3 ± 11,5	-	
Diseases of the hearing organs (H90)	2015	13,7	6,3	2,16	0,49–9,62	53	High	**0,015**
	2016	12,6	2,1	5,94	0,78–45,43	83	Almost complete	
	2017	16,1	2,1	7,56	1,21–47,44	86	Almost complete	
	2015–2017	14,1 ± 4,5	3,5 ± 2,4	5,22 ± 2,77	1,88–8,53	74,0 ± 45,3	-	
Endocrine diseases (E00-E07)	2015	13,6	4,4	2,97	0,55–6,22	66	High	**0,020**
	2016	14,9	4,2	3,51	0,74–16,53	71	Extremely high	
	2017	13,4	4,1	3,11	0,68–15,18	69	Extremely high	
	2015–2017	14,0 ± 2,0	4,2 ± 0,4	3,20 ± 0,70	1,44–9,21	68,7 ± 6,3	Extremely high	
Upper respiratory organs diseases (J30-J84)	2015	8,0	6,3	1,27	0,34–4,62	62	High	**0,024**
	2016	12,6	2,1	5,94	0,79–44,62	83	Almost complete	
	2017	6,8	2,1	3,24	0,40–26,13	69	Extremely high	
	2015–2017	9,1 ± 3,1	3,5 ± 2,4	3,48 ± 2,35	1,11–6,60	71,3 ± 26,6	-	

Table 5

Examination of endothelium-dependent vasodilatation in workers from the compared groups

Brachial artery reaction	Group		Validity of discrepancy (p<0,05)
	Focus group	Reference group	
Growth in diameter ≥10%	45,24	89,47	**<0,001**
Growth in diameter <10%	54,76	10,53	**0,001**
Relative growth in brachial artery diameter, %	9,9 ± 1,7	13,7 ± 1,3	**0,001**
Coefficient of brachial artery sensitivity, arb. units	0,08 ± 0,02	0,20 ± 0,06	**<0,001**

Table 6

Examination of endothelium-dependent vasodilatation in workers from the compared groups with different working experience

Brachial artery reaction	Less than 10 years		Validity of discrepancy between groups (p<0.05)	More than 10 years		Validity of discrepancy between groups (p<0.05)
	Group			Group		
	Focus group	Reference group		Focus group	Reference group	
Growth in diameter ≥10%	51,7	91,3	**0,002**	30,8	86,7	**0,003**
Growth in diameter <10%	48,3	8,7	**0,002**	69,2	13,3	**0,003**
Relative growth in brachial artery diameter, %	10,7 ± 2,0	14,9 ± 1,7	**0,002**	8,2 ± 3,2	11,9 ± 1,8	**0,04**
Coefficient of brachial artery sensitivity, arb. units	0,10 ± 0,02	0,20 ± 0,07	**0,01**	0,06 ± 0,04	0,22 ± 0,10	**0,004**

We applied ultrasound to examine functional state of the vessels endothelium and revealed that a number of miners with low vasodilatation of the peripheral arteries was 5 times higher in the focus group than in the reference one (54.8% against 10.5%, p<0.001), and an average group growth in the brachial artery diameter was 25% lower (9.9±1.7% against 13.7±1.3%, p=0.001), and the coefficient of arteries sensitivity was 2.5 times lower (0.08±0.02 arb. units and 0.20±0.06 arb. units respectively, p<0.001) (Table 5).

As we compared assessment results for functional state of the endothelium in miners with different working experience, we revealed similar trends; in particular, a number of people with unsatisfactory test results was higher in the focus group for any working experience (48.3% and 69.2% against 8.7% and 13.3%; p=0.002–0.003), and functional failure of the endothelium was higher (p=0.004-0.01) (Table 6). Besides, it was interesting to note that a number of people with unsatisfactory vasodilatation increased by more than 20% as their working experience grew (48.3% among those with working experience shorter than 10 years, and 69.2% among those with longer working experience, p=0.02); but it increased only by less than 5% in the reference group (8.7% among those with working experience shorter than 10 years, and 13.3% among those with longer working experience, p=0.22). On the whole, relative risk of functional failure in the endothelium among workers with working experience shorter than 10 years was more than 8 times higher in the focus group than in the reference one (OR=8.6; DI=4.69–11.32; p=0.02); but as underground working experience grew longer than 10 years, this risks practically doubled (OR=14.7; DI=8.13–21.71; p=0.04). We detected that a decrease in functional activity of the endothelium depended on chrome concentration in blood (b0=2.67–4.16; b1=894.33–1129.87; R^2=0.47–0.53; p≤0.001).

The research results prove that a decrease in endothelium-dependent mechanisms of the vascular tone regulation is more apparent in ⅔ miners after just 10 years of work and gives ground for unfavorable forecast for early remodeling of the vascular wall and the consequent cardiovascular pathology development [16, 21].

We performed ultrasound examination of extracranial brachiocephalic arteries and revealed that atherosclerotic changes in vascular walls were registered 2 times more frequently in workers from the focus group than from the reference one (46.5% against 23.7%, p=0.03), and intima-media complex thickness was authentically greater (0.74±0.05 mm against 0.63±0.05 mm, p=0.003) (Table 7).

Table 7

Ultrasound examination of extracranial brachiocephalic arteries in workers from the compared groups

State of extracranial brachiocephalic arteries	Group		Validity of discrepancy (p<0,05)
	Focus group	Reference group	
No signs of atherosclerosis (%)	53,5	76,3	**0,03**
Signs of atherosclerosis (%)	46,5	23,7	**0,03**
Intima-media complex thickness (mm)	0,74 ± 0,05	0,63 ± 0,05	**0,003**

Table 8

Ultrasound examination of extracranial brachiocephalic arteries in workers with different working experience

State of extracranial brachiocephalic arteries	Less than 10 years		Validity of discrepancy between groups (p<0,05)	More than 10 years		Validity of discrepancy between groups (p<0,05)
	Group			Group		
	Focus group	Reference group		Focus group	Reference group	
No signs of atherosclerosis (%)	54,8	82,6	**0,004**	48,8	76,7	**0,04**
Signs of atherosclerosis (%)	45,2	17,4	**0,02**	51,2	23,3	**0,04**
Intima-media complex thickness (mm)	0,75 ± 0,06	0,59 ± 0,04	**<0,001**	0,79 ± 0,09	0,61 ± 0,09	**0,01**

Table 9

Doppler cardiography performed on workers form the compared groups

Test data	Group		Validity of discrepancy between groups (p<0.05)
	Focus group	Reference group	
No US-signs of pathology (%)	12,0	61,1	**<0,001**
US-signs of pathologic changes in the heart detected (%)	88,0	38,9	**<0,001**
Thicker cusps of the aortic and mitral valves (%)	60,0	27,8	**<0,001**
Interventricular septum hypertrophy (%)	54,0	22,2	**<0,001**
Eccentric hypertrophy of the left ventricle (%)	40,0	16,7	**0,01**
Muscle mass of the left ventricle, (g)	227,1 ± 15,3	189,7 ± 23,6	**0,01**
Mass index of the left ventricle cardiac muscle, (g/m^2)	113,7 ± 7,2	100,1 ± 9,9	**0,03**

We should note that miners from the focus group, even with different working experience, ran 3.5-3.8 higher relative risk of atherosclerotic changes in vascular walls than their colleagues from the reference group (OR=3.5–3.8; DI=1.44–9.89; p=0.002–0.03) (Table 8).

We analyzed Doppler cardiography results and revealed that pathologic changes in the cardiac muscle and the valve apparatus were registered 2.3 times more frequently in miners from the focus group than from the reference one (88.0% against 38.9%; p<0.001); they were thicker cusps of the aortic and mitral valves (60.0% against 27.8%; p<0.001), interventricular septum hypertrophy (54.0% against 22.2%; p<0.001), and eccentric hypertrophy of the left ventricle (40.0% against 16.7%; p=0.01) (Table 9). Overall, workers from the focus group ran almost 12 times higher risk of morphological restructuring in the cardiac muscle and the valve apparatus than workers from the reference group (OR=11.7; DI=5.39–18.72; p=0.02). We should note that average age of miners who had these detected changes in the cardiac muscle and the valve apparatus amounted to 40.6±2.7 in the focus group, while it was substantially greater in the reference group and amounted to 48.9±1.4 (p<0.001).

Results obtained via Doppler cardiography prove that miners involved in deep chrome mining and exposed to combined effects produced by adverse physical and chemical occupational factors have morphologic changes in the cardiac muscle and valve apparatus authentically more frequently.

These changes determine an unfavorable forecast of early cardiovascular pathology development.

Conclusions:

1. Existing approaches to assessing working conditions for miners involved in deep chrome mining are predominantly based on examining physical factors of labor processes and pay little attention to chemical ones.

2. 50% miners with their working experience at chrome mines being less than 10 years have early failure of the endothelium functional activity, and it is a leading promoter of cardiovascular pathology; they run 8 times higher relative risks of such pathologies against workers employed on the surface. 10% miners involved in deep chrome mining with their work experience being longer than 10 years suffer from a substantial decrease in functional reserves of the cardiorespiratory system.

3. We detected a direct correlation between a decrease in functional activity of the endothelium and adaptation reserves of the cardiorespiratory system and increased chrome concentration in blood.

4. Miners involved in deep chrome mining run 3.5-12 times higher relative risks of atherosclerotic changes in vascular walls, morphologic changes in the cardiac muscle and valve apparatus than workers employed on the surface.

5. In order to decrease morbidity with cardiovascular pathologies among miners at chrome mines and to implement prevention activities in due time, it is necessary to revise programs for periodical medical examinations and to include the following tests into them: assessment of the vasomotor function of the brachial artery endothelium and Skibinskaya Index calculation for miners with working experience longer than 5 years; Doppler ultrasonography of the brachiocephalic arteries and Doppler cardiography for miners with working experience longer than 10 years.

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