AGE AND EXPERIENCE-RELATED DIFFERENCES IN BLOODCIRCULATION FUNCTIONING OF UNDERGROUND COAL MINERS

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Introduction. Every fourth case of acute diseases of the bloodcirculatory system in miners becomes fatal. Arterial hypertension (AH) is classified as an occupational disease. In those employed in underground work, the depth and rate of development of pathological processes exceed those of workers employed on the ground. The reasons for this situation are associated with a complex of harmful and dangerous factors in the working conditions of miners.

The purpose of the research was to identify some age and experience-related differences in bloodcirculation functioning in miners employed at underground coal mining enterprises.

Materials and research methods. 31 miners of 32–58 years (43.5 ± 1.2) with a total work experience of 13–28 years (20.6 ± 0.7), underground shift work experience in the occupation – 8–22 years (15.7 ± 0.7) were measured: heart rate (HR), systolic and diastolic blood pressure (BPS, BPD), height and weight. Haemodynamic indices, Kerdo's (VIK) and bloodcirculatory failure (BFI) indices were calculated, the type of bloodcirculation self-regulation was determined. Data were analyzed at the $p < 0.05$ level.

Results. According to the average group data, BPS and BPD were found in the zone of high norm, HR – at the upper limit of the norm, stroke volume (SV) and cardiac output (CO) – in the zone of the «average» functional state of the bloodcirculatory system, peripheral vascular resistance (PVR) – in the «below average» zone, BFI – in the zone of tension of regulatory systems, VIK – in tendency to parasympathicotonia. 39 % of miners showed BP in the zone of moderate AH, 6 % – in medium AH, 100 % – showed impaired self-regulation of bloodcirculation: 81 % – by vascular type, 19 % – by cardiac type. With an increase in age and experience, BPS, BPD, mean dynamic pressure, PVR increased, SV, CO decreased, and VIK decreased with age. With an increase in underground work experience, the asymmetry of BPD increased and the asymmetry of BPS decreased in miners. The functional state of the miners' bloodcirculatory system passed into the class of «below average» at the age of 48, at a total work experience of 24 years, and at an underground work experience – 18 years.

Conclusions. The miners showed an unfavourable state of the bloodcirculatory system: in 45 % – increased BP corresponded to AH, in 100 % of the examined – impaired self-regulation of blood circulation, which is considered as a risk factor for the development of AH. The early transition of the functional state of the bloodcirculatory system to the «below average» class reflects the pronounced adverse effect of working conditions. An increase in BPD asymmetry and a decrease in BPS asymmetry ($p < 0.05$) with an increase in underground work experience can be associated with the involvement of specific mechanisms of adaptation to work, in particular, cardiorenal. The identified isolated age-related increase in parasympathicotone is not consistent with the population norm and indicates the presence of adverse effects of a non-production origin, reflecting the need for comprehensive preventive measures to improve the working and living conditions of miners to extend their occupational longevity.

Key words: miners, underground work, shift work, night work, hypertension, parasympathicotonia, functional state of the bloodcirculatory system, harmful and dangerous working conditions

Introduction

The pathology of the bloodcirculatory system is the cause of more than half of deaths worldwide and two out of three deaths in Ukraine [1]. Every fourth case of acute diseases of the bloodcirculatory system at the workplace among coal miners becomes fatal [2]. Arterial hypertension (AH) – the pathological basis of strokes and heart attacks – is classified as an occupationally determined disease due to the relative risk and the etiological share of production factors in its development [3]. Diseases of the bloodcirculatory system in miners develop faster and are diagnosed at a younger age than on average in the population, the incidence of complications, life-threatening situations, disability due to the bloodcirculatory system pathology are higher [3, 4]. In underground workers, the depth and rate of development of pathological processes significantly exceeds those in ground workers: they have a higher cardiac risk [5], the prevalence of hypertension is significantly higher [3] and the relative risk of its development estimated as 8-fold [4], the relative risk of developing atherosclerotic changes in the vascular wall, morphological restructuring of the myocardium and its valve apparatus is 3.5–12 times higher [4], 20 times higher is the rate of decline in endothelial function – one of the main predictors of hypertension [5]. The reasons for the situation are associated with a complex of harmful and dangerous factors in the working conditions of miners, almost each of which is a risk factor for the development of the bloodcirculatory system diseases [6]: dust, an unfavorable microclimate, noise, vibration, the severity and intensity of the work performed, which under the underground work are more unfavorable and are aggravated by the lack of natural lighting, increased atmospheric pressure, its sharp drops when descending into the mine and ascending to the surface, hypogeomagnetic field, ionizing radiation, confined space at a high risk of explosions and fires with a threat to health and life,

that leads to the development of chronic stress [2, 4, 7]. At the same time, the age-experience regularities of the dynamics of the state of the bloodcirculatory system in miners, which reveal effective directions for improving prophylaxis, remain insufficiently studied.

The purpose of the research was to identify some age and experience-related differences in bloodcirculation functioning in miners employed at underground coal mining enterprises.

Materials and methods of research

The research was carried out at the enterprises of the Lviv coal basin. The research protocols were approved by the Bioethics Committee of the State Institution «Kundiiev Institute for Occupational Health of National Academy of Medical Sciences of Ukraine». Practically healthy workers who signed informed consent were invited to participate in the studies. Thirty one miners (miner of the working face, spinner, mining underground) of the underground coal mines [men aged 32–58 years old { $M \pm m$: (43.5 ± 1.2) yrs} with the total work experience of 13–28 years {(20.6 $\pm$ 0.7) yrs} and underground work experience in the occupation – of 8–22 years {(15.7 $\pm$ 0.7) yrs}] working rotating 6-h shifts during a 6-day working week were observed at prophylaxis examination in the hospital (during day time, one observation per worker) by measured height, weight; heart rate (HR), blood pressure systolic and diastolic (BPS, BPD) in the upper extremities using digital blood pressure monitor DS-1902 «Nissei».

Hemodynamic parameters were calculated: Pulse Pressure ($PP = BPS - BPD$), Mean-Dynamic Pressure ($MDP = 0.42 \cdot PP + BPD$), Stroke Volume ($SV = 100 + 0.5 \cdot PP - 0.6 \cdot BPD - 0.6 \cdot Age$), Cardiac Output ($CO = SV \cdot HR$), Periphery Vascular Resistance ($PVR =$

MDP $\cdot$ 1333 $\cdot$ 60/CO)), Kerdo's Vegetative Index ($KVI = (1 - BPD/HR) \cdot 100 \%$) [8], Bloodcirculatory Failure Index ($BFI = BPS/HR$) [9]. Bloodcirculation self-regulation type was defined [10].

Blood pressure levels were evaluated using WHO-ISH Guidelines (1999) [11]. SV, CO and PVR levels were assessed using Buzunov's Classification (1991) [12]. The bloodcirculatory system functional state was evaluated as a mean of these three parameter assessments [13]. Blood pressure asymmetry was defined when the difference in BPS or BPD scores between left and right hands was higher than 10 mm Hg [14].

The data were analysed at $p < 0.05$ using basic statistics and Pearson correlation (Ms Excel 2007). A mathematical model of the linear regression analysis was applied.

Results

According to the mean group data, in miners systolic and diastolic blood pressure parameters were found in the high norm zone [11], the pulse – in the zone of the upper boundary of the norm [15] (Table 1). Parameters of SV and CO were found in the «middle class» of the functional state of the bloodcirculatory system, the PVR – in the «below the average» class – according to the classification of V. A. Buzunov [12]. BFI reflected the strain in the regulatory systems of the bloodcirculatory system functioning [16], VIK – tendency to parasympaticotone [8]. The asymmetry of arterial blood pressure on the upper limbs was found in the zone of the norm [14].

Analysis of individual data has shown that 45 % of the surveyed manifested blood pressure in the

Table 1

Parameters of the bloodcirculatory system functioning in miners (N = 31)

№	Parameter of bloodcirculatory	Min	Max	M $\pm$ m	Qualification of the mean group value of the parameter	References
1	BPS – left hand (mm Hg)	120	150	136 $\pm$ 1	high norm	WHO Guidance, 1999
2	BPD – left hand (mm Hg)	70	100	86 $\pm$ 1	high norm	WHO Guidance, 1999
3	HR – left hand (beat/min.)	68	88	80 $\pm$ 1	norm (top)	
4	BPS – right hand (mm Hg)	115	150	132 $\pm$ 1	high norm	WHO Guidance, 1999
5	BPD – right hand (mm Hg)	70	95	85 $\pm$ 1	high norm	WHO Guidance, 1999
6	BPS difference at left and right hands (mm Hg; abs)	0	5	4.5 $\pm$ 1.0	norm	Cheremisina A. Yu. et al., 2013
7	BPD difference at left and right hands (mm Hg; abs)	0	5	1.5 $\pm$ 1.0	norm	Cheremisina A. Yu. et al., 2013
8	SV (ml)	33,7	61,4	47.40 $\pm$ 1.44	middle class	Buzunov V. A., 1991
9	CO (ml)	2831	4748	3783 $\pm$ 102	middle class	Buzunov V. A., 1991
10	PVR (kPa $\cdot$ s/l)	1737	3101	2327 $\pm$ 82	class below middle	Buzunov V. A., 1991
11	VIK (c. u.)	-20,5	2,4	-7.30 $\pm$ 1.75	norm	Kérdő I., 1966
12	BFI (c. u.)	1,5	1,93	1.70 $\pm$ 0.02	strain in regulatory systems	Tebenova K. S., et al., 2015

hypertension zone: 39 % – in the zone of moderate hypertension, 6 % – in the zone of medium hypertension. The normal type of bloodcirculation self-regulation has been found in nobody. The vascular type of blood circulation self-regulation was revealed in 81 % of the surveyed, cardiac one – in 19 %. Asymmetry of systolic or diastolic blood pressure (> 10 mm Hg) has been detected in no miner.

Age and experience-dependent significant increase in BPS, BPD, MDP, PVR, age and experience-dependent significant decrease in SV, CO and age reduction in VIK (increase in parasympathetic severity) were revealed.

The significant negative correlation of the underground experience in the occupation with the difference in BPS on the upper limbs was found, positive one – with the difference of BPD, in the absence of the significant correlation with age or total work experience (Table 2).

The functional state of the bloodcirculatory system of miners passes to the class «below average» (according to the classification of V. A. Buzunov, 1991) at the age of 48 years old, at a total work experience – of 24 years, at the underground experience in the occupation – of 18 years (Table 3). The functional state of the bloodcirculatory system of miners passes from the class «below average» to the «low» class at the age of 52 years old, at a total work experience – of 27 years, hypothetically – at the underground experience in the occupation – of 57 years. Hypothetically the functional state of the bloodcirculatory system of miners could move into the «very low» class at the age of 60 years old or at the total work experience of 32 years. In practice, miners at the age of more than 58 years old or at the total work experience for more than 28 years or more than 22 years of underground experience in the occupation in our sample were not identified.

Table 2

Correlation of the parameters of the bloodcirculatory system functioning with age and work experience of miners ($N = 31$, $p < 0.05$)

Parameter	Age	Total work experience	Underground shift work experience in miner occupation
BPS – left hand	0.42	0.40	
BPD – left hand	0.50	0.44	
BPS – right hand	0.41	0.46	
BPD – right hand	0.52	0.36	
BPS difference			-0.41
BPD difference			0.39
SV	-0.80	-0.60	
CO	-0.81	-0.60	
Mean dynamic pressure	0.50	0.46	
Peripheral vascular resistance	0.80	0.62	
Vegetative index of Kerdo	-0.38		

Discussion

According to the mean group data, parameters of the bloodcirculatory system functioning in miners are located at the upper boundaries of the physiological norm, which could reflect the certain degree of a strain in the system functioning, as evidenced by the BFI in the strain zone – on the background of «average» – «below the average» class of the functional state of the bloodcirculation system.

VIK in the zone of negative values indicates a tendency to parasympatocotone that, according to the literature, is associated with an increase in stress and a decrease in the adaptive reserves of the bloodcirculatory, nervous and sympathetic-adrenal systems [17–19], with the development of fatigue [16] or prepathological states under unfavourable conditions.

Table 3

**Age and experience-related changes in the functional state of the bloodcirculatory system
in miners (according to the classification of V. A. Buzunov, 1991)**

Pass to the class	Age (years)	Total work experience (years)	Underground shift work experience (years)
Below mean	48	24	18
Low	52	27	> 40
Very low	60	32	> 40

avourable ecology [20], is characteristics of persons engaged in tension labour, shift and night work [16, 21, 22].

The impaired bloodcirculatory self-regulation is a prognostically unfavorable sign indicating the high risk of arterial hypertension development in miners [10], which is consistent with the literature data on its occupational conditionality [3] and prevalence among miners [23].

The identified age and experience-dependent significant decrease in SV and CO with an increase in PVR, BPS, BPD, MDP is consistent with the literature data on the age-related weakening in the pump function of the heart, the loss of elasticity and hypertrophy of large arterial vessels, reducing the volume of blood flow [24, 25].

The revealed age reduction in VIK (amplification of parasympaticotone) in the absence of a significant correlation with the work experience does not have a simple correlate in the literature. It is known that the population rate is the age-related increase in sympathetic tone [25] – as an adaptive body reaction to the previous environment conditions against the background of an age reduction of high-speed functions. According to our data, an increase in work experience in the occupations of intense mental operator work has been associated with a decrease in VIK, while the age reduction in VIK was noted only in the first night shifts with a high production load [22]. Hence, the age-related strengthening in para-

sympaticotone in miners probably should be linked not so much to the specifics of working conditions, as to the circumstantial factors (possibly to unfavourable living conditions, harmful habits, low educational level, etc. [7]).

It was revealed that with an increase in the underground shiftwork experience of miners, the asymmetry of diastolic blood pressure increases and the asymmetry of systolic blood pressure decreases, that may indicate the involvement of specific adaptation mechanisms to the underground working conditions of miners, in particular – to high levels of noise and vibration, possibly at night, by involving cardio-renal mechanisms [26].

The transition of the functional state of the bloodcirculatory system in miners to the «below average» class at the age of 48 years old, at a total work experience of 24 years or under the underground experience in the occupation of 18 years, it is evidences on the adverse working conditions leading to the early deterioration of the bloodcirculatory system in miners, and the need to apply comprehensive measures to improve the conditions of their work and life to preserve the employment potential and to extent their occupational longevity.

Conclusions

1. The miners showed the unfavourable state of the bloodcirculatory system: 45 % – manifested an increased blood pressure corresponding to the hypertension of moderate

- (in 39 %) or the average (in 6 %) stage, all 100 % of the examined – showed an impaired bloodcirculatory self-regulation (81 % – by the vascular type, 19 % – by cardiac), which is considered in the literature as a risk factor for the arterial hypertension development.
2. The functional state of the bloodcirculatory system in underground coal miners passes to the «below average» class at the age of 48, at a total work experience of 24 years or at the underground experience with systematic night shifts – of 18 years, which reflects the pronounced adverse effect of underground shift work of miners onto the functional state of the bloodcirculatory system and substantiates the preferential age of their retirement.

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