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DEVELOPMENT OF SYSTEMS FOR DETECTING AND ELIMINATING ALCOHOL FROM THE HUMAN BODY BASED ON THE HUMAN RESPIRATORY SYSTEM MODEL

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Abstract. *The relevance of the development of technical systems designed to monitor the physical condition of vehicle drivers, operators of technological equipment and personnel of critical information objects and blocking access to hardware and software controls of these objects in cases where it is established that their health indicators deviate from the norm, including being under the influence of alcohol is argued. It has been shown that, due to the volatility of alcohol, it is possible to determine its concentration in the blood by analyzing deep alveolar air. The system for remote monitoring and control of mobile and stationary objects and controlling the blood alcohol content of the personnel of these objects based on the developed integrated circuit, controlled by a program module written in the object-oriented programming language C++ is presented. The relevance of the development of technical systems for the treatment of alcohol withdrawal syndrome which allow to reduce the pharmacological load on the patient and increase the efficiency of the treatment process ensuring a reduction in economic costs is argued. Because hypoxia is one of the pathogenetic links of alcoholism the use of the normoxic therapeutic compression method in narcology for treatment both the main drug addiction disease and concomitant neurological and therapeutic diseases that patients with addiction to psychoactive substances suffer from is justified. For the purpose of technical implementation of the normoxic therapeutic compression method a positive pressure oxygenation system was proposed. In the process of testing the system it was found that the use of normoxic therapeutic compression in complex treatment is more effective compared with hyperbaric oxygenation in reducing the severity of pathological craving for alcohol mainly due to the vegetative component. The use of the proposed system makes it possible to optimize and improve the effectiveness of assistance in relieving pathological craving for alcohol during alcohol withdrawal syndrome as well as to reduce the time of patients' stay in the hospital.*

Keywords: *alcohol withdrawal syndrome, normoxic therapeutic compression, automated oxygen therapy, hyperbaric oxygenation, positive pressure oxygenation system, blood alcohol content, breath analysis for alcohol content, remote monitoring, management of sources of increased danger, state of alcohol intoxication.*

Introduction

One of the current threats to people's safety and health is alcohol addiction [1]. It accounts for up to 20-30% of healthcare costs, since people who abuse alcohol have

concomitant diseases associated with it [2], which in turn significantly affects the increase in mortality. Alcohol intoxication and alcohol withdrawal syndrome, which is a human condition after prolonged consumption of alcoholic beverages, lead to metabolic disorders, which are considered the main pathogenetic factors of the disease. The first stage in the treatment of alcohol withdrawal syndrome is to identify symptoms of alcohol withdrawal, which form within 6–48 hours after completely stopping or reducing the amount of ethanol consumption and last from 2–3 days to 2–3 weeks. The primary goal of treating alcohol withdrawal is to relieve symptoms, as well as prevent complications and initiate long-term alcohol therapy. However, intensive drug therapy may cause an increase in the toxic load. In this connection, there is a need for technical solutions that can reduce the pharmacological load on the patient's body and increase the efficiency of the treatment process, ensuring a reduction in economic costs [1].

It should be taken into account that managing sources of increased danger while intoxicated poses a particular danger, since in such a state a person's thought processes slow down, concentration and speed of muscle reaction decrease, and vision deteriorates [2]. Sources of increased danger include both moving objects, such as vehicles, and stationary objects, such as technological equipment in workshops or laboratories. Critical information objects used to ensure the functioning of environmentally hazardous and socially significant industries require increased attention. Since disruption of the normal operating mode of critical information facilities can lead to man-made emergencies. According to the State Automobile Inspectorate of the Ministry of Internal Affairs of the Republic of Belarus, in 2023, 16 thousand cases of driving vehicles while intoxicated were identified [3]. At the same time, every 7th traffic accident is caused by drunk drivers. In the Russian Federation, in 2023, GOST [4] was approved and put into effect, establishing requirements for driver condition monitoring systems intended for installation on vehicles. Thus, there is a need to develop technical means to identify the fact that a vehicle driver, operator of a critical information object or technological equipment is intoxicated and block the ability to control this source of increased danger.

Development of a system for monitoring the blood alcohol content of personnel of mobile and stationary facilities

Alcohol, which is ethyl alcohol (ethanol) from a chemical point of view, is a colorless liquid that has a calming and suppressive effect on the central nervous system [1]. Low molecular weight, relative insolubility in fat and good solubility in water ensure its rapid penetration into body tissues. The presence of most drugs in the human body can only be detected through a blood or urine test, which involves the use of complex laboratory separation and measurement methods. It should be understood that in order to determine a person's state of intoxication, it is necessary to analyze the concentration of these substances coming from the arterial blood specifically to the brain. The main problem is that only venous blood is always taken for analysis, and not arterial blood, since this is too dangerous a procedure. Since alcohol is highly soluble in water, the more water a tissue contains, the more alcohol it absorbs from arterial blood. Accordingly, until the moment when the blood-tissue system comes into

balance, the alcohol concentration in venous blood will be less than in arterial blood. Thus, until the absorption of alcohol from arterial blood into the tissues is complete, the analysis of venous blood will lead to an underestimated alcohol level.

The volatility of alcohol, according to Henry's law, causes it to enter the exhaled air during evaporation from the pulmonary arterial blood during gas exchange. Moreover, the relationship between the equilibrium concentrations of alcohol in the deep alveolar air and pulmonary arterial blood is clearly defined. Since the temperature of deep alveolar air is relatively constant at 34°C, the actual concentration ratio for a given temperature is used, which is close to 2300:1 [5]. This ratio takes into account the possibility of small fluctuations in temperature and hematocrit. Since alcohol does not dissolve in fat, and red blood cells have an outer fatty coating, alcohol is actually contained in the blood plasma. The ratio of human red blood cell to plasma volumes, which is reflected by the hematocrit, can vary and lead to small changes in this ratio. In addition, we take into account the fact that when you inhale, alcohol-free inhaled air, passing through saliva, is to some extent saturated with alcohol, and when you exhale, the concentration of exhaled air saturated with alcohol in the lungs, passing through saliva, is partially reduced.

Thus, by measuring the concentration of alcohol in the deep alveolar air it is possible to determine its concentration in the pulmonary arterial blood, which carries it to the brain. In order to technically implement the method of measuring the concentration of alcohol in a person’s exhaled air and controlling access to sources of increased danger, a system for remote monitoring and control of mobile and stationary objects and monitoring the blood alcohol content of the personnel of these objects was developed [6]. The proposed system was based on the developed integrated circuit [7], which is intended for use in the field of computer technology and can be used to control access to control hardware and software of objects without changing their design. To control the proposed system in the Microsoft Visual Studio 6.0 development environment in the object-oriented programming language C++, a corresponding software module was developed [8]. The developed system for monitoring the blood alcohol content of personnel at mobile and stationary facilities also contains a GPS module that allows you to determine the coordinates and speed of a moving object, for example a vehicle, which is transmitted to the control unit. The control unit, through software, controls the equipment installed at the facility and has a storage device for storing all received information. Before starting, as well as periodically while working with technological equipment, the operator/driver, using a device for determining the level of alcohol in the blood based on an electrochemical sensor, undergoes a procedure for checking for the presence and level of alcohol. The test data is sent to the control unit. If the operator/driver is intoxicated, the control unit activates the actuator blocking device, which blocks the technological equipment or the vehicle engine. In the event that blocking the actuator is not possible due to the technological process or because the vehicle is in motion, the actuator blocking device turns on the hazard warning signal without blocking the actuator. At the same time, by means of a modem connected to the control unit, information about the speed and location of the moving object, as well as verification data, is sent via a data transmission medium to the dispatcher’s server and terminal located at the control center. The dispatcher contacts law enforcement

agencies and/or enterprise management and provides the details of the intoxicated operator/driver, his location and other necessary information. The server accumulates all information received from the control unit. Dispatchers are designed to monitor and control mobile and stationary objects by transmitting commands to the control unit via a data transmission medium and a modem. Data transfer between the control center server and the facility control unit can be carried out via any type of radio communication.

Development of a positive pressure oxygenation system

Hypoxia is one of the pathogenetic links of alcoholism. Its occurrence and progression is caused by chronic intoxication effects on the functions of external respiration, disturbances in the binding and transport of oxygen by hemoglobin, its absorption by tissues, as well as a decrease in the intensity of redox processes. In drug addiction patients, the hypoxic factor directly depends on the severity and duration of the disease, and it reaches its greatest severity during periods of acute intoxication and withdrawal syndrome. Thus, for the purpose of non-drug detoxification, the use of oxygen in the complex treatment of alcoholism seems promising, since it enhances the metabolism of ethanol and its derivatives, in particular acetaldehyde, stimulates the activity of the central nervous system, normalizes immunogenesis, and improves the functional state of the cardiovascular system.

Hyperbaric oxygen therapy is one of the inhalation methods that are used in narcology in the treatment of both the main drug addiction disease and concomitant neurological and therapeutic diseases that suffer from patients with addiction to psychoactive substances. The use of this method in clinical practice is based on the significant dissolution of oxygen in body fluids, namely plasma, lymph, and cerebrospinal fluid. During hyperbaric oxygenation, the patient inhales oxygen with a concentration of 100% under conditions of increased pressure from 2 to 3 atmospheres, which ensures the formation of reactive oxygen species and oxygenation of the body without the participation of red blood cells [9]. The use of hyperbaric oxygenation in conjunction with other therapeutic measures is used in the treatment of patients with various poisonings, peripheral vascular insufficiency, peritonitis, air embolism, anaerobic infection and other somatic disorders.

The combination of methods of drug therapy and hyperbaric oxygenation makes it possible to reduce the treatment time for patients with alcoholism, as well as to avoid complications in severe cases, since oxygen potentiates the effect of psychotropic and antihistamines, reduces the body's resistance to insulin and other drugs. As a result, it is possible to significantly reduce the dosage of medications, and often carry out drug-free therapy.

At the same time, it is necessary to note the risks of using hyperbaric oxygenation, which are caused by the cellular localization of the resulting reactive oxygen species and their concentration, as well as an incorrectly selected dose of oxygen. It should be taken into account that the oxygen mixture at elevated pressure is explosive and fire hazardous.

Thus, as an alternative to the hyperbaric oxygenation method, it is proposed to use the normoxic therapeutic compression method. The difference lies in the use of

excess pressure in a narrow range of 100-120 mmHg, that is, up to 15% above atmospheric pressure. This is due to the fact that at a higher pressure, which is used during hyperbaric oxygenation, due to an increase in the partial pressure of oxygen in the inhaled air, its accumulation due to tissue respiration, the oxygen content increases both in red blood cells and in the blood plasma. As a result, free radical activity, lipid peroxidation and blood plasma viscosity increase. These processes can nullify the therapeutic effect of the method, and in severe patients lead to an increase in pathological changes in the body. In the case of an increase in excess pressure in a small, optimal range for the body's absorption of oxygen during normoxic therapeutic compression, as a result of the normalization of free radical oxidation processes and the activation of tissue respiration at the mitochondrial level [10], energy production in the ischemic zone is restored and self-regulation of blood microcirculation is resumed. In this connection, the method of normoxic therapeutic compression is successfully used in the treatment of such serious diseases as hypertension, stroke, heart attack, migraine, and many others. Normoxic therapeutic compression allows you to restore the energy supply to the cell and cell membrane receptors, which increases the effectiveness of medications while reducing the therapeutic dose and, as a consequence, the toxic effect. Accordingly, the combination of the normoxic therapeutic compression method with the use of antioxidants significantly increases the therapeutic effect.

The advantages of the normoxic therapeutic compression method compared to the hyperbaric oxygenation method are: safety, high therapeutic effect, absence of contraindications with the exception of claustrophobia, hypertensive crisis and diabetic coma.

Thus, it seems relevant to develop a medical system for conducting sessions of normoxic therapeutic compression, including for alcoholism and drug addiction. For the purpose of technical implementation of the normoxic therapeutic compression method, a portable oxygenation system under excess pressure was developed [11]. The proposed system relates to medical equipment, in particular to systems for treatment with oxygen under excess pressure with automated control of the proportion of inhaled oxygen, as well as positive pressure and temperature inside the system body and can be used for the prevention and treatment of patients in conditions of increased absolute and partial pressure of oxygen environment. This system contains a durable polyester body coated on both sides with urethane, equipped with a double zipper with an air-isolating gasket, which allows the pressure chamber to safely maintain high pressure, providing the patient with easy entry/exit. The housing is also equipped with two safety valves. Throughout the entire treatment session, the compressor continuously supplies purified air from the room into the body. When the set pressure inside the housing is reached, the safety valve automatically opens. This is necessary to eliminate excess CO2 content and maintain maximum overpressure. The second valve is a backup valve. Additionally, oxygen is supplied to the system housing through an oxygen concentrator. A distinctive feature of the developed system is that, using appropriate sensors, it measures the pulse and oxygen content in the patient's bloodstream, as well as the oxygen content and temperature inside the case. Based on the results of measuring the pulse and oxygen content in the patient's bloodstream, the system determines the patient's oxygen status and, based on this, as well as the results of

measuring the oxygen concentration and temperature inside the case and the specified desired oxygen concentration, controls the concentration of supplied oxygen and the temperature inside the case. The use of the proposed technical solution allows for automatic adjustment of the parameters of oxygen concentration and temperature inside the body of a portable oxygenation system under excess pressure according to the desired values set based on the patient's condition. In addition to treating alcohol withdrawal syndrome, this system can be used in the treatment of acute respiratory failure syndrome, cerebral ischemia, cerebral palsy, hypertension, atherosclerosis, migraine, autonomic dystonia, traumatic brain injury, autoimmune diseases, multiple sclerosis, as well as in sports medicine.

Results and discussion

Today, the practice of using systems that block the ability of drivers under the influence of alcohol to drive vehicles demonstrates high efficiency: the number of accidents caused by drivers under the influence of alcohol is reduced, and the number of repeated arrests of drivers under the influence of alcohol is reduced. At the same time, it should be noted the positive social effect consisting in the ability to retain the right to drive a vehicle if the type of activity is associated with it, provided that this system is installed after the initial arrest while intoxicated.

However, in order for the installation of such systems both in the Republic of Belarus and the Russian Federation to become widespread, amendments to the current legislation are necessary, as well as the active participation of insurance companies.

Additional attention should be paid to measures to protect against driver/operator actions aimed at falsifying blood alcohol test results. It should be noted that the systems can be equipped with sensors for temperature and humidity of the analyzed air, which will distinguish a real exhalation from a simulated one, as well as means of personal identification, which will protect against possible substitution of the driver/operator. Organizational measures include repeated checks at random intervals.

The testing of the proposed oxygenation system under excess pressure involved 160 patients in a state of alcohol withdrawal, who suffered from alcohol dependence and were inpatient treatment at the state institution "Republican Scientific and Practical Center for Mental Health": 62 people underwent hyperbaric oxygenation, 56 - normoxic therapeutic compression along with standardized drug therapy, 42 – only standardized drug therapy in accordance with medical care protocols. For each patient, the following were studied: clinical and psychological parameters of alcohol withdrawal syndrome in daily dynamics [12, 13].

The main research methods were the clinical-psychopathological method with dynamic monitoring of the patients' condition, psychometric, and statistical.

To assess the severity of alcohol withdrawal symptoms, the CIWA – A (Clinical Institute for Withdrawal Assessment – for Alcohol) rating scale was used [14].

For a comprehensive assessment of pathological craving for alcohol, a scale for pathological craving for alcohol was used [1].

The use of the method of normoxic therapeutic compression in combination with standardized drug therapy for alcohol withdrawal syndrome, compared with therapy with

drugs alone, makes it possible to more effectively, starting from the third day of treatment, reduce the severity of pathological craving for alcohol, mainly due to the affective and vegetative components, and also provide more promising dynamics of its reduction.

The use of the hyperbaric oxygenation method in combination with standardized drug therapy for alcohol withdrawal syndrome compared to drug therapy alone allows for more effective positive dynamics, starting from the fifth day of treatment, reducing the severity of pathological craving for alcohol, mainly due to affective, vegetative and ideational components.

The use of normoxic therapeutic compression in complex treatment was more effective, compared with hyperbaric oxygenation, in reducing the severity of pathological craving for alcohol, mainly due to the autonomic component.

Conclusion

Thus, the proposed system for remote monitoring and control of mobile and stationary objects and monitoring the blood alcohol content of the personnel of these objects [15] is intended for use in any vehicles and stationary objects, allows you to monitor the level of alcohol in the blood of drivers and personnel of these objects, block actuators if the driver/operator is intoxicated and report this to law enforcement agencies and/or enterprise management. The system also monitors the speed, location and movement of moving objects in real time, notifies drivers about the situation on the route, based on information received from other controlled objects, and allows operators to control remote objects.

The proposed oxygenation system under excess pressure [16] ensures the use of the normoxic therapeutic compression method. The combination of which with standardized methods of pharmacotherapy makes it possible to optimize and improve the effectiveness of assistance in relieving pathological craving for alcohol during alcohol withdrawal syndrome, and to reduce the time of patient stay in the hospital.

References

1. Narcology: national guide / Ed. N.N. Ivanets, I.P. Anokhina, M.A. Vinnikova. – M.: GEOTAR-Media, 2008. – 720 p.

2. Dawson, D.A. Alcohol consumption, alcohol dependence, and all cause mortality. / D.A. Dawson // Alc. Clin. Exp. Res. – 2000. – Vol. 24, no. 1. – P. 72-81.

3. Belarusian telegraph agency BelTA [Electronic resource]. – Access mode: https://www.belta.by/interview/view/netrezvye-voditeli-i-bespravniki-kak-gai-boretsja-s-problemoj-i-chto-grozit-narushiteljam-8639: 02/13/2024.

4. Motor vehicles. Driver condition monitoring system (alcohol lock). General technical requirements: GOST R 70637-2023. – Enter. 04/01/2023. – Moscow: Russian Institute of Standardization, 2023. – 28 p.

5. J. Mack Cowan The Relationship of Normal Body Temperature, End-Expired Breath Temperature, and BAC/BrAC Ratio in 98 Physically Fit Human Test Subjects / J. Mack Cowan, James M. Burris, James R. Hughes, Margaret Parker Cunningham // Journal of Analytical Toxicology. – 2010. – Vol. 34, №5. – P. 238–242.

6. System for remote monitoring and control of mobile and stationary objects and monitoring the blood alcohol content of the personnel of these objects: Pat. 7487 Rep. Belarus / O.B. Zelmansky, B.V. Zelmansky – u20110066; appl. 02/11/2011; publ. 05/06/2011 // Official bulletin / National center for intellectual property – 2011. – No. 4(81). – P. 220–221.

7. Integrated circuit of a device for monitoring and controlling technological equipment as a function of time: certificate for the topology of an integrated circuit No. 96 Rep. Belarus / O.B. Zelmansky – No. t20120012; appl. 03/27/2012; publ. 09/17/2012 // Official bulletin / National center for intellectual property – 2012. – No. 6. – P. 318.

8. Software module for monitoring and managing mobile and stationary objects: certificate of registration of computer program No. 1701-KP publ. 14/03/2024 Rep. Belarus / O.B. Zelmansky / National center for intellectual property – 2024.

9. Thom, S. R. Hyperbaric oxygen – its mechanisms and efficacy/ Thom, S. R.// Plast Reconstr Surg. – 2011. – Vol. 127(Suppl 1). - S. 131–141.

10. Kazantseva N.V., Voskresenskaya O.N. and others. The influence of various HBO regimes on free radical processes and microcirculation in the treatment of patients with initial manifestations of cerebral circulatory failure. \\AND. Neuropathology and Psychiatry 1994, No. 2, pp. 41-44.

11. Portable hyperbaric oxygenation system: Pat. 11669 Rep. Belarus / O.B. Zelmansky, B.V. Zelmansky, E.I. Davidovskaya, O.A. Ivanushchik – u 20170277; application 08/15/2017 ; publ. 01.02.2018 // Afitsyiny bulletin. / National center intellectual. Ulasnastsi. – 2018. – No. 2(121). – P. 154.

12. Kopytov, D. A. Evaluation of the effectiveness of complex treatment of alcohol withdrawal syndrome taking into account markers of the hepato-biliary system / D. A. Kopytov, L. I. Kudin, A. V. Kopytov, O. B. Zelmansky // Military medicine. - 2020. - No. 3(56). - P. 32-43.

13. Kopytov, D. A. Dynamics of lipid status in alcohol withdrawal syndrome against the background of complex treatment / D. A. Kopytov, L. I. Kudin, A. V. Kopytov, O. B. Zelmansky // Medical journal. - 2020. - No. 3(73). - P. 75-83.

14. Sullivan J.T. et al. Assessment of alcohol withdrawal: The revised clinical institute withdrawal assessment for alcohol scale (CIWA-Ar). British Journal of Addiction 1989; (89): 1353-1357.

15. Zelmansky, O. B. System for remote monitoring and management of mobile and stationary objects and controlling of alcohol content in the blood of the personnel of these objects / O. B. Zelmansky // Medicine and high technologies. - 2024. - No. 2. - P. 22–29.

16. Zelmansky, O. B. Technical support for the application of the normoxic therapeutic compression method in drug treatment practice / O. B. Zelmansky // Medicine and high technologies. - 2023. - No. 4. - P. 34–39.

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