EFFECT OF HYPERBARIA ON THE ELECTRICAL EXITABILITY OF THE VESTIBULAR ORGAN IN RABBITS

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ABSTRACT

This paper presents a study of the effects of hyperbaric conditions on the vestibular organ during sham air exposures in an animal model. The proper functioning of the vestibular organ determines diving safety due to the limited role of the organ of vision underwater, especially in our latitudes.
The study was conducted on 16 rabbits by recording the animal's head movements generated by a 'galvanic test.' The tests were performed during compression at positive pressures of 1, 2, 3, 4, 5, and 6 atm and then during decompression at the same overpressures.
A decrease in the sensitivity of the vestibular system to stimuli was found as the pressure increased.
Keywords: hyperbaric conditions, vestibular organ, rabbit.

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INTRODUCTION

The vestibular organ is of even greater importance to a diver in a pressurised atmosphere underwater than it is to a person in normal conditions on land. Working conditions under water reduce the range of activity of some of the human senses. In particular, the function of the visual analyser is reduced due to the poor light conditions already at relatively shallow depths which worsen with further immersion. The narrowing of the range of information provided by the visual analyser about a person's spatial location places the responsibility for the diver's spatial orientation primarily on the vestibular organ. The situation is aggravated by the fact that the body position changes during movement, as the free diver usually moves in the direction of the long axis of the body and not, as in land conditions, perpendicular to it. This causes additional difficulties in spatial localisation of the diver underwater.

At greater depths, where it is completely dark, or at night, a diver without proper instruments can easily lose orientation and will sink deeper and deeper instead of swimming towards the surface. The narcotic effect of the compressed breathing gases on the diver, occurring already from a depth of 30 m, makes it difficult to critically assess the information provided to the diver by his sensory organs [1,2,3,4,5 et al.]. This can easily result in an accident or even death of the diver. Therefore, the efficiency of the vestibular organ is of great practical importance to the diver. In the literature available to us, we have not encountered a study of this issue.

THE AIM OF THE STUDY

The aim of this study is to investigate the effect of air hyperbaria on the electrical excitability of the animal vestibular organ in a model experiment. Such an experiment provides an opportunity to exclude the influence of other factors present in the diver's underwater environment such as water temperature, lack of light, etc.

MATERIAL AND METHODOLOGY OF STUDIES

The study was carried out on 16 rabbits (8 females and 8 males), of the Wiener breed, weighing approximately 2 kg, fed standardised feed. The experiments were carried out in a typical training and treatment pressure chamber adapted for testing the electrical excitability of the vestibular organ. The excitability of the vestibular organ was determined using the so-called "galvanic test." Electrodes in the form of surgical clamps with soldered wires connected to a current source outside the chamber were applied to the skin of the mastoid region of the test rabbit. The current intensity was indicated by a microammeter with an accuracy of 10 μA. The measure of vestibular organ excitation was the current intensity causing a change in position of the rabbit's head when the direction of current flow was changed. Changes in head position were recorded by a system consisting of a light source placed outside the chamber in a porthole, a photodiode fixed to the animal's head and an amplifier (Brüel-Kjaer type 2604) placed outside the chamber. Movements of the rabbit's head caused a change in the SEM of the aligned system: light source - photodiode. This change was recorded after an appropriate amplification on a recorder (2305 by Brüel-Kjaer) connected to the amplifier. Forced movements were recorded when the current was switched on, thus eliminating random movements of the rabbit's head. In addition, the animal's response was observed through the chamber illuminator.

The rabbit was placed in a cage immobilising it in the pressure chamber by positioning it under one of its portholes. Under normal pressure, the recording system was tuned and the value of the current necessary to induce the head inclination of the rabbit was determined when the direction of the current flow was changed, i.e. a typical galvanic test with observation of the second vagal reflex was performed [according to 6,7]. The first (eye deviation) and third (nystagmus) reflexes could not be recorded under the conditions of our experiment. These determinations were repeated at least three times and the mean value of the current magnitude was determined. Then, with the pressure in the chamber of 1 atn. (atn - atmospheres above atmospheric pressure), 2 atn., 3 atn., 4 atn., 5 atn., and 6 atn. The determinations that were made were the same as at normal pressure. The time taken to perform the tests in the chamber ranged from 30 minutes to 3 h. With decompression performed according to the Haldane tables, all measurements were repeated at the corresponding chamber pressure levels, i.e. 5, 4, 3, 2, and 1 atn. and at normal pressure.

The air temperature in the pressure chamber was approximately 19°C with slight fluctuations of up to ± 1.5°C. CO_2 levels did not fluctuate because the tests were conducted in a normal high-volume pressure chamber intended for humans and ventilation was used in accordance with the regulations specifying its values for human exposure.

RESULTS

The results of the study are presented in Table 1. These are averages of the averages obtained in the study carried out on 16 rabbits.

Fig.1 graphically shows the dependence of the current intensity required to stimulate the vestibular organ in rabbits on the air pressure in the pressure chamber.

Using the Student's t-test, the results obtained at the different chamber pressures were compared with each other. It was found that statistically significant differences ($p<0.05$) occurred between the values obtained at normal pressure and at pressures 1 atn., 2 atn. and higher, with the values obtained at 5 and 6 atn. very significantly different from the initial values ($p<0.01$). Then, based on the calculation of the correlation coefficient (Pearson's test), it was concluded that there was some correlation between the value of the air pressure in the chamber and the increase in the current required to stimulate the vestibular organ in hyperbaric conditions. Using the Fischer's formula we concluded that the calculated correlation coefficient was statistically significant ($p<0.01$).

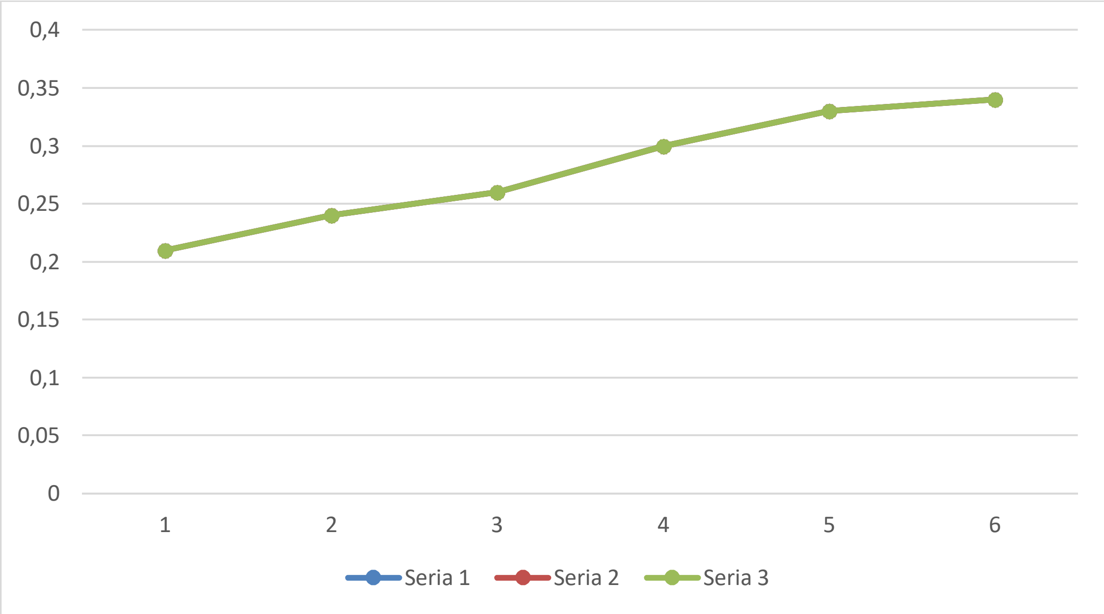

Fig. 1. The dependence of excitability of the vestibular organ in rabbits on air pressure in the pressure chamber.

Tab. 1

Current intensity necessary to excite the vestibular organ in rabbits under hyperbaric conditions (averages of averages).

Pressure in atn.	0.	1	2	3	4	5	6
Current intensity in mA	0,2	0,21	0,24	0,26	0,3	0,33	0,34
Đ	0,04	0,026	0,049	0,06	0,048	0,045	0,049

During decompression, similar results were obtained only in a reverse order, with the return to the baseline depending on the length of time the rabbit was in hyperbaric conditions. It should be noted that changes in the electrical excitability of the vestibular organ only became apparent after at least 10-20 minutes of being in the chamber under increased air pressure. This was taken into account for our study starting from a pressure of 1 atn.

DISCUSSION OF RESULTS

Experimental studies on the effects of hyperbaric conditions on the excitability of the vestibular organ were carried out with 16 rabbits placed in a pressure chamber of the training and treatment type, i.e. under conditions corresponding to those of a regular diving training for humans. The excitability of the vestibular organ of the rabbits was determined using the so-called "galvanic test." The choice of the galvanic test for determining vestibular organ excitability in experimental animals in hyperbaric conditions was dictated primarily by the specifics of the hyperbaric experiment and the possibility of a very precise determination of the magnitude of the relevant stimulus, which did not change in the test despite changes in air pressure. It also ensured good reproducibility over short time intervals, which is necessary in this type of research.

Purkinje (1820) first drew attention to the vagal response to a galvanic stimulus applied to the head [8]. However, to date, there are still a number of disputed views as to where the galvanic stimulus is triggered. Some authors suggest that the stimulation already takes place in the sensory elements of the vagus nerve. Yet, the occurrence of nystagmus following galvanic stimulation of the vestibular nerve is also observed after the removal of the vagus. Dohlman [9] found a typical reaction after direct irritation of the vestibular ganglion. Huizinga [10], however, observed it in experimental animals after the removal of this ganglion using stronger currents. It may be that the stimulus is amplified in this ganglion. Mittermeier [11] doubts whether it is possible to selectively irritate one vagus. He believes that irritation also transfers to the opposite side. Bos and Jongkees [12] give various possibilities for the positioning of the electrodes for the galvanic test. They consider it most advantageous to place them in the region of the mastoid processes or scutes, as this allows the weakest stimuli to be applied. This positioning of the electrodes was already pointed out in 1871 by Hitzig [13].

Summarising the views of these authors, as well as the Polish ones, such as Miodoński [14], Mitrinowicz-Modrzejewska [15], Hurynowicz [6] and others, it should be assumed that using a galvanic test with the placement of electrodes on the region of both mastoid processes, as in our experience, we obtain irritation of the entire vestibular system, and not only the vagus itself. This test is therefore particularly suitable for the study of the vestibular organ in hyperbaric conditions, as it explains the behaviour of the entire organ under these circumstances. Behnke [16], Davis [1], Dolatkowski [2,3], Haldane [4], Huszcza [5] et al. report that compressed air exerts a narcotic effect on the body from a pressure of 4-6 atn. They link this to the specific effects of nitrogen on the central nervous system and to disturbances in cellular oxidation processes caused by abnormal CO_2 and O_2 levels in tissues. At higher pressures, at which oxygen partial pressure exceeds 3 atn., toxic effects of oxygen also occur. In our test, at air pressures of up to 6 atn. this effect can be excluded. Studies by Foulconer et al [17] conducted in a pressure chamber on the effects of nitrous oxide on EEG images, showed a decrease in bioelectrical brain function as the pressure in the chamber increased. Bennet [18] found an attenuation of the bioelectrical response of the cerebral cortex to an acoustic stimulus in experimental animals exposed at elevated pressure to breathing mixtures based on oxygen and argon, helium or nitrogen.

Dolatkowski et al [3] also found an increase in simple reaction time in divers in a compressed air atmosphere. The results obtained in the present study confirm the observations described above about the effects of hyperbaric conditions on the central nervous system. Our study showed that the excitability of the vestibular organ of rabbits exposed to compressed air in a pressure chamber decreased with increasing pressure in a statistically significant manner. The decrease in excitability was also dependent on exceeding a certain time of staying under these conditions. Comparing the results of these studies with data from the literature, it appears that the reduction in vestibular excitability is due to the specific effects of compressed air on the central nervous system. As a result, nerve conduction may be weakened or central nervous system function may be reduced, requiring stronger irritation of peripheral receptors to respond to a given stimulus. This is also supported by the occurrence of the described changes in the magnitude of the electrical stimulus inducing irritation of the vestibular organ only after a certain time needed for the compressed air to act on the central nervous system.

The reduction in excitability of this organ under the influence of air hyperbaria is of great practical importance for the diver. A diver staying underwater for a prolonged period of time, especially at greater depths, due to the reduced excitability of the vestibular organ, can easily lose orientation when changing the position of the body quickly. This is particularly dangerous for the classical diver, as loss of balance has already led many times to the diver falling from the work site, e.g. from the deck of a sunken ship, or from the edge of a hatch to greater depths leading to crushing. Therefore, the reduced excitability of the vestibular organ should be taken into account when organising underwater work and when overcoming water obstacles. Also, exercises of the sense of balance should be introduced into the diving training programme. This could have a beneficial effect on the diver's ability to compensate for the negative effects of compressed air on the vestibular organ.

CONCLUSIONS

1. The excitability of the vestibular organ to a galvanic stimulus in rabbits exposed to compressed air in a pressure chamber decreases as the pressure increases.
2. These changes appear to occur as a result of the specific effects of compressed air on the central nervous system.
3. The reduction in excitability of the vestibular organ under the influence of compressed air may be important when conducting underwater work at greater depths. This should be taken into account when planning them and when preparing the diver for such tasks.

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