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EVALUATION OF DECOMPRESSION SICKNESS RISK IN SATURATED AIR AND NITROX DIVES JUDGED ON THE BASIS OF CHANGES IN HAEMOSTASIS

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INTRODUCTION

During the decompression phase of a dive, divers may suffer from the effects of inert gas supersaturation. The result may be formation of intravascular gas bubbles. The gas-fluid interface surrounding a gas bubble acts like a foreign body, that activates factor XII (Hageman's) of the coagulation system. The transformation of factor XII into the active form is a mechanism triggering the endogenous coagulation system and indirectly, the processes of kininogenesis, fibrinolysis and processes in the complementary system. The stimulation of the endogenous coagulation system activates thrombine, leading to the aggregation of blood platelets and release of their content (Boussuges *et al.*, 1995; Elliott and Philp, 1993; Moon *et al.*, 1992; Olszanski and Czestochowska, 1995; Olszanski *et al.*, 1990; Olszanski et al., 1993). The evaluation of decompression tables, and of individual sensitivity to decompression disease, is primarily based on the detection of symptoms. Thus not on physiological, but pathophysiological criteria.

The above situation imposes research into such diagnostic methods that would allow for the evaluation of the decompression system applied. Apart from the "bends" criteria and Doppler monitoring of gas bubbles and of blood flow, the evaluation of haemostasis may well be regarded as an indicator that the decompression is correct.

The main objective of the present work was to evaluate the variability of the basic and complementary parameters of the coagulation system in air and nitrox saturated diving.

METHODS

The study was undertaken using 38 divers (males), aged 20 - 33 years. The divers remained on a plateaua phase for 4 days and nights, and each day they performed 30 minutes work on a cycle ergometer, and conducted dives with breathing apparatus in the water filled part of the chamber. The partial pressure of oxygen during the saturated nitrox dives was 50 kPa. At 12 m, the oxygen content in the chamber atmosphere was maintained at 23%. Decompression was carried out continuously (Doboszynski and Lokucijewski, 1986). In all, there were 17 saturated air diver-decompressions and 21 saturated nitrox diver-decompressions. The depth of the saturated air dives was between 18 m and 20 m,

and for the nitrox dives between 18 m and 45 m. With regards to pulmonary toxicity, the depth limit of air saturated dives may be regarded as a depth of 18 m.

The examination of the blood platelets was performed in a Ceel-Dyn analyser 1600 (Abbot), the aggregation level with Born's method, with ADP as the aggregation factor. The aggregation in time was defined after 1, 2 and 3 minutes, after the addition of ADP to the platelet abundant plasma. The prothrombine indicator (PT) was determined with the aid of Simplastin Excel S kits (Organon Technica), caoline - kefaline time (APTT) with Platelin LS diagnostic kits (Organon Technica), and fibrinogen (FIB) with Hemolab Fibrinomat kit (Bio-Merieux). The recordings were carried out by means of coagulometer Option 4 (Bio-Merieux), the coagulation factors VII, X, XII (norm 70% - 120%) were determined with the use of Behring kits with the chromogenic method (Raszeja-Specht and Kabata, 1995). Average values of the dependent variables were evaluated by means of the Student's T-test. The examinations were performed before and after the dives.

The programme of saturated dives was based on the principles of the Polish system (Doboszynski *et al.*, 1986). The dives were performed at the Department of Diving Gear and Underwater Work Technologies of the Naval Academy in Gdynia.

RESULTS

Table 1: Results of the examinations on selected parameters of haemostasis and on complement C3 and C4 in divers, before and after saturated air dives. The number of diver-decompressions was 17.

Parameter of haemostasis	Arithmetic mean BEFORE & AFTER air exposure	Standard deviation BEFORE & AFTER air exposure	t - value
Platelets k/ul	233.56 156.50	190.17 40.35	1.8524*
Fibrinogen mg/dl	297.63 242.81	60.65 26.66	4.3539*
Factor X %	121.97 86.92	24.07 32.15	8.8341*
Factor XII %	115.88 68.89	23.21 22.88	7.6058*
C3	79.64 102.04	13.00 18.06	-7.0831*
C4	21.13 26.33	4.23 3.25	-6.0131*

* t - alpha critical value = 1.8331 at the significance level alpha = 0.95

Differences in the mean values of: plateletal blood cells (platelets), fibrinogen, coagulation factors X and XII and of the complement components C3 and C4, before and after the air saturated diving, were statistically significant ($p < 0.05$).

Table 2: Results of examinations of selected haemostatic parameters and on the complement system in divers, before and after the saturated nitrox divings. The number of diver-decompressions was 21.

Parameter of haemostasis	Arithmetic mean BEFORE AFTER nitrox exposition	Standard deviation BEFORE AFTER nitrox exposition	t - Value
C3	78.01 92.60	10.33 11.79	-9.7724*
C4	18.08 21.80	2.15 2.08	-7.8087*

* t - alpha critical value = 1.8331 at the significance level alpha = 0.05

The differences in the mean values of: the complement components C3 and C4 before and after the saturated nitrox diving were statistically significant ($p<0.95$).

CONCLUSIONS

The problem of saturated dives, even to small depths, has not been satisfactorily solved yet, even though they bridge deep dives. In contrast to saturated heliox dives, research on saturated nitrox diving has always been, and still is, far behind the problem of decompression being the main obstacle.

A key role in the process of saturation and desaturation of the body is played by the perfusion of the tissues. In the case of defective decompressions it gets disturbed. It is extremely difficult to assess, to what extent perfusion has been affected by the gas bubbles induced by decompression. The only known method of estimating the likehood of decompression sickness occurring, is the method of critical supersaturation of the body (Sićko, 1995). This method is based on comparative analysis in a known proportion of cases of decompression sickness. There is no generally accepted method for verifying decompression tables based, not on the decompression sickness morbidity, but on shifts in haemostatic parameters preceding the onset of pathological symptoms (bends).

The present study compared two types of saturated dives: air diving and nitrox diving. After the air dives we noticed a reduction of the coagulation factors X and XII of fibrinogen and blood platelets, as well as an increase of some components of C3 and C4 complement systems. These changes were statistically significant. The ADP induced proportional changes of the blood plateletal aggregation after the air saturated dives were marked for the increase of aggregation proportions, indicating increased sensitivity of the blood platelets to the ADP aggregating factor. These observations are corroborated with reference data (Boussages *et al.*, 1995; Elliot and Philp, 1993; Martin and Nichols, 1972;

Olszanski and Czestochowska, 1995; Olszanski *et al.*, 1990, 1993; Philp and Gowdey; Valeri *et al.*, 1974).

Saturated nitrox dives resulted in an increase of only some of the components of the C3 and C4 complement. These changes were statistically significant (Berg *et al.*, 1993; Shastri *et al.*, 1991; Stevens *et al.*, 1993).

That the decrease of the level of factor XII does not affect APTT is due to its concentration, sufficient to maintain full efficiency of the endogenic system. The reduction of the activity of this factor observed in divers may suggest its exhaustion, because of the activation of the coagulation system mediated by the endogenic system. Analogously, the reduction of the factor X does not affect prothrombine index (PT), and does not disturb functions of the exogenous system. Absence of changes within factor VII indicates the absence of direct activation of the exogenous system by the tissue factor (5). The reduced concentration of fibrinogen may result from its increased exhaustion due to activation of the coagulation cascade (5).

Changes in parameters of haemostasis detected in saturated air dives, such as: reduction of the blood platelet count and of coagulation factors (X and XII), and increased sensitivity of blood platelets to aggregation factor ADP, confirm activation of the coagulation system and risk of decompression sickness, whereas in saturated nitrox dives the results of examinations on haemostatic parameters point to a significant reduction in the parameters of the coagulation system.

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