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HPNS during rapid compressions of men breathing $He-O_2$ and $He-N_2-O_2$ at 300 m and 180 m

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Rostain JC, Gardette-Chauffour MC, Naquet R. HPNS during rapid compressions of men breathing $He-O_2$ and $He-N_2-O_2$ at 300 m and 180 m. Undersea Biomed Res 1980; 7(2):77–94.—The effects of the various breathing mixtures $He-N_2-O_2$ (N_2 = 9% and 4.5%) and of the $He-O_2$ mixture have been studied during four identical dives to 300 m (compression time = 4 h). Complementary experiments were made at 180 m with the mixtures $He-N_2-O_2$ (N_2 = 10% and 20%) and $He-O_2$ (compression time : 15 min). The results of these dives showed that tremor was slight and that there was no difference between the various mixtures at 180 m and between the $He-N_2-O_2$ at 4.5% and $He-O_2$ at 300 m. However, the presence of different percentages of nitrogen in the $He-O_2$ mixture did not prevent the occurrence of EEG modifications at 180 m or 300 m; their intensity appeared to be as great (or even greater) than with the $He-O_2$ mixture. Furthermore, at 300 m, with the $He-N_2-O_2$ mixture, certain subjects showed paroxysmal EEG modifications not observed with the $He-O_2$ mixture. In all cases, the physical condition of the subjects prevented them from working immediately upon reaching the depth of 300 m; a delay of 4 h was necessary before they could work correctly. This behavioral improvement preceded the regression of the EEG modifications, which were found between the 10th and the 14th h of stay at 300 m. These results show that the presence of nitrogen reduces certain clinical symptoms of the HPNS but does not influence the EEG records; in certain cases nitrogen enhanced EEG modifications. The mode of action of nitrogen seems to be relatively complex. Complementary studies are necessary to find the best combinations between compression methods and the composition of the mixture.

HPNS	EEG
tremor	pressure
nervous system	compression rate
helium	nitrogen

Deep diving in a helium-oxygen atmosphere induces a certain number of behavioral disturbances. Bennett (1) described the existence of nausea, vertigo, and, above all, tremor, which he attributed to helium (i.e. helium tremor), during rapid compression to 180 m. Later, during simulated dives between 300 and 365 m, Brauer et al. (2) and Fructus et al. (3) demonstrated a series of symptoms that they grouped under the heading "high pressure nervous syndrome" (HPNS). These symptoms were confirmed later by Bennett and Towse (4) during a dive to 457 m.

Since then, various authors have tried to discover the causes of the HPNS and to reduce its intensity. From these studies, the important role played by the method and speed of compression in the extent and intensity of various symptoms was shown (4, 5, 6). In particular, a slow compression interrupted by stages was shown to reduce the HPNS considerably (4, 7–10). Using gases that have "narcotic" properties, such as nitrogen, certain authors (11, 12, 13) have attempted to attenuate the signs of hyperexcitability of the central nervous system that they found in animals.

Bennett et al. (13) also tried a breathing mixture of helium-oxygen-nitrogen (trimix) in man, and they described an attenuation and even a "suppression of the HPNS" for certain concentrations of nitrogen during rapid compressions to 300 m.

We have examined the possibility of using $He\text{-}N_2\text{-}O_2$ mixtures during rapid compression. This work is a first stage in our studies of the use of $He\text{-}N_2\text{-}O_2$.

METHODS

Dives to 300 m

Using the same compression curve (C.E.H., COMEX), we carried out four dives to 300 m (CORAZ).

The compression from 0 m to 300 m lasted 4 h. Stages of 30-min duration were allowed at 100 m, 180 m, and 240 m. The speed of compression was (Fig. 1): 4 m/min between 0 and 100 m; 2 m/min between 100 and 240 m; 1 m/min between 240 and 300 m. The compressions always began at the same hour.

The quantity of nitrogen in the breathing mixture and the number of diver-subjects for each dive were: 9% for CORAZ I (3 divers); 4.5% for CORAZ II and III (2 divers); 0% for CORAZ IV (2 divers). The subjects were COMEX professional divers. Subjects A and B served in both CORAZ I and II (2 months between the first and the second dive). The physical characteristics of the diver-subjects are provided in Table 1.

Preceding each dive the subjects were confined in the hyperbaric chambers. The stay at the bottom varied from 32 to 81 h. The decompressions were performed with $P_{I_{O_2}}$ of 500 mb (CORAZ I) or 600 mb (CORAZ II, III, and IV) and lasted from 151 to 136 h. The conditions for these four dives are presented in Table 2.

Dives to 180 m

We carried out another series of dives at 180 m using the same compression (15 min from 0 to 180 m) (C.E.H. COMEX and GISMER). With the $He\text{-}O_2$ respiratory mixture, the quantity of nitrogen was 800 mb (partial pressure of atmospheric air at the beginning). With the $He\text{-}N_2\text{-}O_2$ mixture, the partial pressure was 1900 mb for five subjects (10% at 180 m) and 3800 mb for three subjects (20% at 180 m). The compressions always began at the same hour.

The subjects were professional divers (three divers from the Navy, two divers from COMEX). Their physical characteristics are provided in Table 3. The same subjects carried out two or three series of dives. The time interval between dives was from 2 to 12 months depending on the subject. The stay at the bottom was 105 min and the decompression was carried out in 56 h.

Neurophysiological methods

During these dives the tests were always carried out at the same hours. Neurological tests were used to detect the presence of dysmetry, myoclonus, and tremor. The tremor was

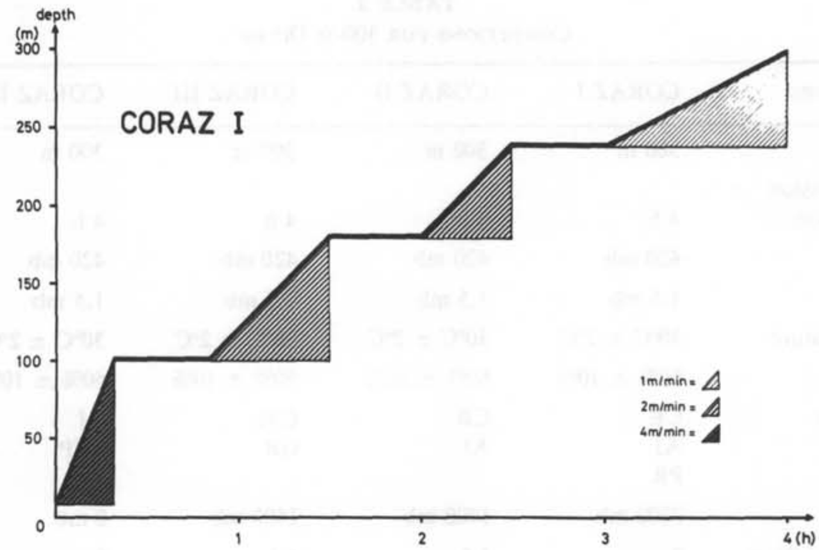

Fig. 1. Profile of the CORAZ dives.

measured by accelerometry with the aid of a geophone (Geospace HS-J) placed on the middle finger of the right hand. The measurements were made with the right arm extended horizontally from the body and were repeated several times during the compressions and every day at fixed times throughout the dive and confinement (3 epochs of 20 s each).

The signals were recorded on magnetic tape and analyzed on a PDP-12 computer; the final analysis was performed on 3 successive averaged sequences of 17.5-s duration each.

The subjects were equipped with electrodes of the "Hameçons ECEM" type implanted in the right scalp at predetermined positions: fronto-polar, central, mid-temporal, occipital. These electrodes were maintained in place by gauze and collodion gel for the duration of the confinement and the dive (9, 14).

TABLE 1
PHYSICAL CHARACTERISTICS OF SUBJECTS IN 300-M DIVES

Dive	Subject	Age yr	Weight kg	Height m
CORAZ I	A (CB)*	29	71	1.65
	B (AJ)*	28	75	1.74
	C (PR)	35	80	1.85
CORAZ III	A (GM)	23	65	1.71
	B (GR)	34	68	1.65
CORAZ IV	A (GJ)	31	82	1.83
	B (MJP)	39	70	1.75

*Also served as subjects in CORAZ II.

TABLE 2
CONDITIONS FOR 300-M DIVES

Conditions	CORAZ I	CORAZ II	CORAZ III	CORAZ IV
Depth	300 m	300 m	300 m	300 m
Compression duration	4 h	4 h	4 h	4 h
PI_{O_2}	420 mb	420 mb	420 mb	420 mb
PI_{CO_2}	1.5 mb	1.5 mb	1.5 mb	1.5 mb
Temperature	30°C ± 2°C	30°C ± 2°C	30°C ± 2°C	30°C ± 2°C
H_2O	60% ± 10%	60% ± 10%	60% ± 10%	60% ± 10%
Subjects	CB AJ PR	CB AJ	GM GR	GJ MJP
PI_{N_2}	2800 mb	1400 mb	1400 mb	0 mb
% N_2 at 300 m	9	4.5	4.5	0

The EEG activity was recorded by bipolar derivation on an electroencephalograph continuously during compression, sequentially (30 min) during stay at bottom and decompression, and sequentially (20 min) on magnetic tape for subsequent computer analysis. We carried out a Fourier analysis on average sequences of 7.5 s to obtain their power spectra (9, 15).

RESULTS

Clinical symptoms: dives to 300 m

Tremor

In all cases a slight high-frequency tremor was observed.

CORAZ I (N_2 = 9%) (Figs. 2 and 3). At the surface all three subjects had values of tremor relatively identical and stable over time (Subject A (M ± SD) = 38.5 ± 1.7; Subject B = 34.7 ± 0.5; Subject C = 40.8 ± 4.5).

During the compression from 0 to 300 m, the tremor presented no significant modification in Subjects A and C but was more accentuated in Subject B. On arrival at 300 m, a decrease of

TABLE 3
PHYSICAL CHARACTERISTICS OF SUBJECTS IN 180-M DIVES

Subject	Age yr	Weight kg	Height m
BUL	36	58	1.67
COM	31	70	1.71
MAR	34	85	1.84
MOR	29	74	1.73
PAN	24	84	1.81

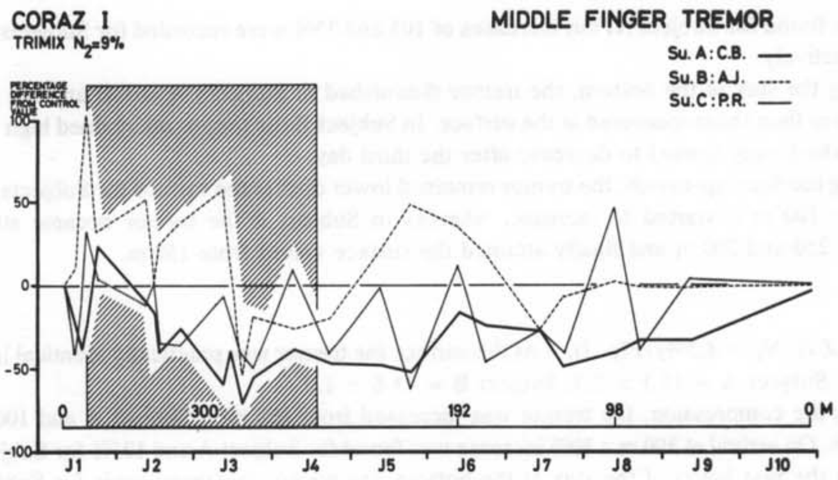

Fig. 2. Evolution of middle finger tremor of three subjects as a function of depth during CORAZ I dive. Shaded portion represents the stay at 300 m. J = day.

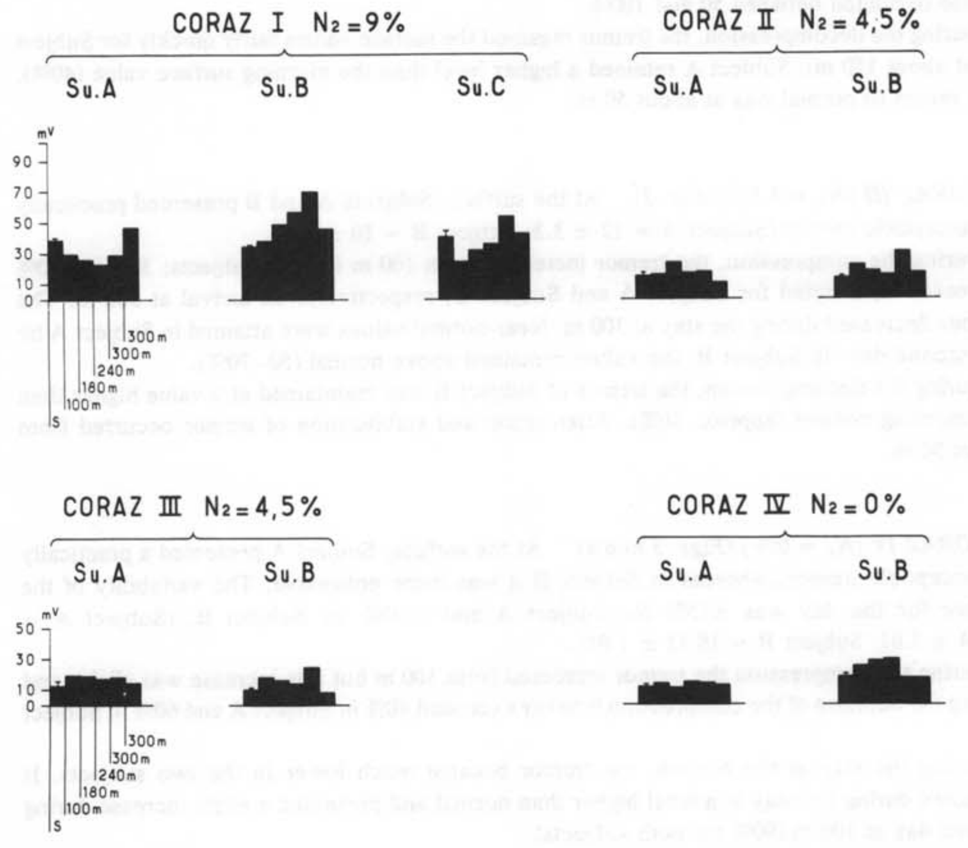

Fig. 3. Changes in middle finger tremor during the first day (D1) of the dive for four experiments.

25% was found for Subject A, but increases of 103 and 33% were recorded for Subjects B and C, respectively.

During the stay at the bottom, the tremor diminished in Subjects A and C and the values were lower than those measured at the surface. In Subject B the tremor maintained high values (50%), which only started to decrease after the third day.

During the decompression, the tremor remained lower than at the surface for Subjects A and C. From 100 m it started to increase, whereas in Subject B the tremor became stronger between 250 and 200 m and finally attained the surface values from 150 m.

CORAZ II (N_2 = 4.5%) (Fig. 3). At the surface the tremor was practically identical in both subjects: Subject A = 13.3 ± 2.3; Subject B = 13.6 ± 1.0.

During the compression, the tremor was increased from 180 m in Subject A and 100 m in Subject B. On arrival at 300 m a 30% increase was found for Subject A and 125% for Subject B.

During the first hours of the stay at the bottom, the tremor increased again for Subject A (107%) while it started to decrease in Subject B. By the evening of the same day, Subject A attained normal values. In Subject B the tremor remained slightly more intense (30%). In Subject A we saw a further increase in tremor during the third and fourth days of the stay (maximum increase, 50%). Subject B's values remained higher than at the surface; the increase oscillated between 50 and 100%.

During the decompression, the tremor regained the surface values fairly quickly for Subject B (at about 150 m); Subject A retained a higher level than the morning surface value (40%). The return to normal was at about 50 m.

CORAZ III (N_2 = 4.5%) (Fig. 3). At the surface, Subjects A and B presented practically imperceptible tremor (Subject A = 12 ± 3.3; Subject B = 10 ± 1.2).

During the compression, the tremor increased from 100 m in both subjects; 50 and 140% increases were noted for Subject A and Subject B, respectively, on arrival at 300 m. The tremor decreased during the stay at 300 m. Near-normal values were attained in Subject A by the second day. In Subject B, the values remained above normal (50–70%).

During the decompression, the tremor of Subject B was maintained at a value higher than the morning control (approx. 50%). Attenuation and stabilization of tremor occurred from about 50 m.

CORAZ IV (N_2 = 0%) (Figs. 3 and 4). At the surface, Subject A presented a practically imperceptible tremor, whereas in Subject B it was more noticeable. The variability of the tremor for the day was ±15% for Subject A and ±10% for Subject B. (Subject A = 10.44 ± 1.61; Subject B = 18.13 ± 1.81).

During the compression the tremor increased from 100 m but this increase was slight, and during the duration of the compression it never exceeded 40% in Subject A and 60% in Subject B.

During the stay at the bottom, the tremor became much lower in the two subjects. It remained during the stay at a level higher than normal and presented a slight increase during the last day at 300 m (90% for both subjects).

During the decompression, the tremor was greater in the morning than the evening. Normal values were attained from a depth of 100 m.

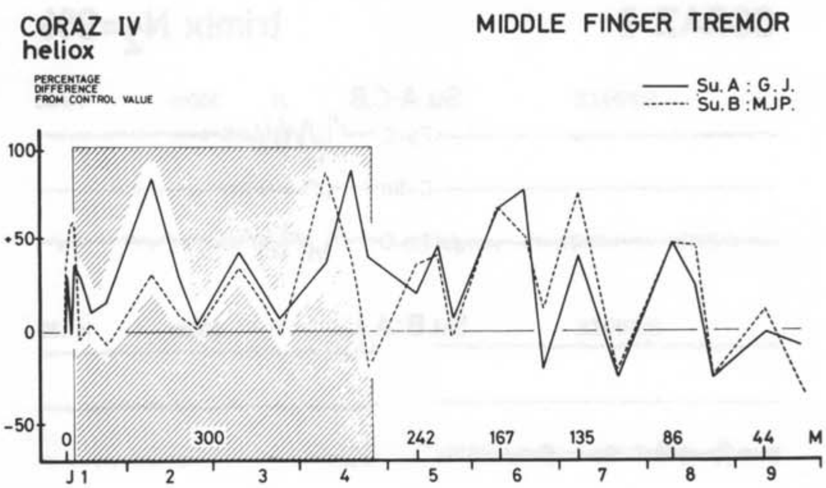

Fig. 4. Evolution of middle finger tremor of the two subjects as a function of depth during CORAZ IV dive. Shaded portion represents the stay at 300 m. J = day.

Dysmetria

In the trimix dives, dysmetria was more or less marked in some of the subjects on arrival at 300 m. It was more pronounced in the heliox dive. In every case it disappeared 4 to 6 h after arrival at the bottom.

Other behavioral disturbances: dives to 300 m

In general, the divers were not in a physical state that would allow them to work immediately on arrival at 300 m.

In the trimix dives, a transitory euphoria was observed on arrival at 300 m; outside these periods sleepiness and lassitude were observed. The subjects were not interested in work or the tests that were given to them.

With the heliox mixture, these problems were not encountered with the exception of lassitude, which was always present.

With He-N_2-O_2 mixtures, 4 h after arrival at the bottom, the subjects could work and showed better performances than on their arrival at the bottom.

EEG symptoms: dives to 300 m

CORAZ I (N_2 = 9%). The EEG modifications for the three subjects are shown in Fig. 5. From 180 m the alpha-posterior amplitude decreased in all subjects. Between 180 and 240 m, bursts of theta activity appeared on the frontal and central leads of the three subjects. The frontal lead had the highest amplitudes.

From 240 m, EEG paroxysmal discharges appeared in two subjects. These were of high amplitude and occurred frequently in Subject A. From 240 m, EEG patterns resembling stage I sleep appeared a few seconds after the subjects were asked to close their eyes. During the stay at the bottom, paroxysmal discharges disappeared about 16 h after arrival, at the same time as the other EEG modifications (theta activity, drowsiness) were decreasing.

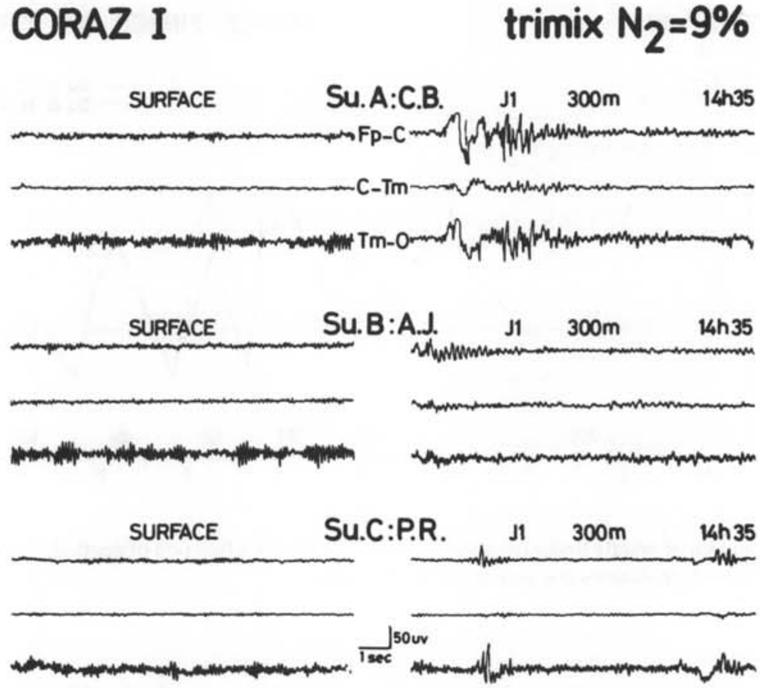

Fig. 5. Subjects A (top), B (middle), C (bottom), CORAZ I. EEG with eyes closed at the surface and at 300 m. Fp. C = Fronto polar/central; C. Tm = Central/mid-temporal; Tm. O = mid temporal/occipital. J = day.

The development of the EEG activity in one subject during the dive was seen in the power spectra for the frequency bands delta, theta, alpha, and beta for the three derivations analyzed. The power spectra were established only for periods with no EEG paroxysmal discharges. (Figs. 6 and 7)

An increase of the power of theta activity was seen in all the derivations. This increase was very great in the frontal lead during the compression. (240 m, *Subject* A: Fp. C +1000%; C. Tm +300%; Tm. O +300%; *Subject* B: Fp. C +800%; C. Tm +100%; Tm. O +200%; *Subject* C: Fp. C +7000%; C. Tm +3500%; Tm. O +1400%) and during the first hours of the stay at 300 m.) The maximum was found between 2 h and 6 h after the end of compression. (Maximum values: *Subject A:* Fp. C +3500%; C. Tm +350%; Tm. O +300%. *Subject B:* Fp. C +2400%; C. Tm +300%; Tm. O +250%. *Subject C:* Fp. C +8800%; C. Tm +6400%; Tm. O +2300%.)

The power of theta activity began to decrease at the 7th h of the stay at 300 m. From the second day of the stay and during the stay, the values of the power spectra of theta frequency were lower than the first day in all the subjects, but were relatively high in comparison to surface values within some subjects. (*Subject* A: 200–300%; *Subject* B: 500–1000%; *Subject* C: 300–100%.)

The power spectra also showed an increase of the delta frequency activities. This increase, which appeared at about 240 m, was less than that of the theta activities and was only apparent in two subjects. The maximum reading was obtained between the second and sixth hour of stay at the bottom at 300 m (300%), on the frontal and/or central leads. The amplitude was less beginning on the second day, but remained higher than surface readings.

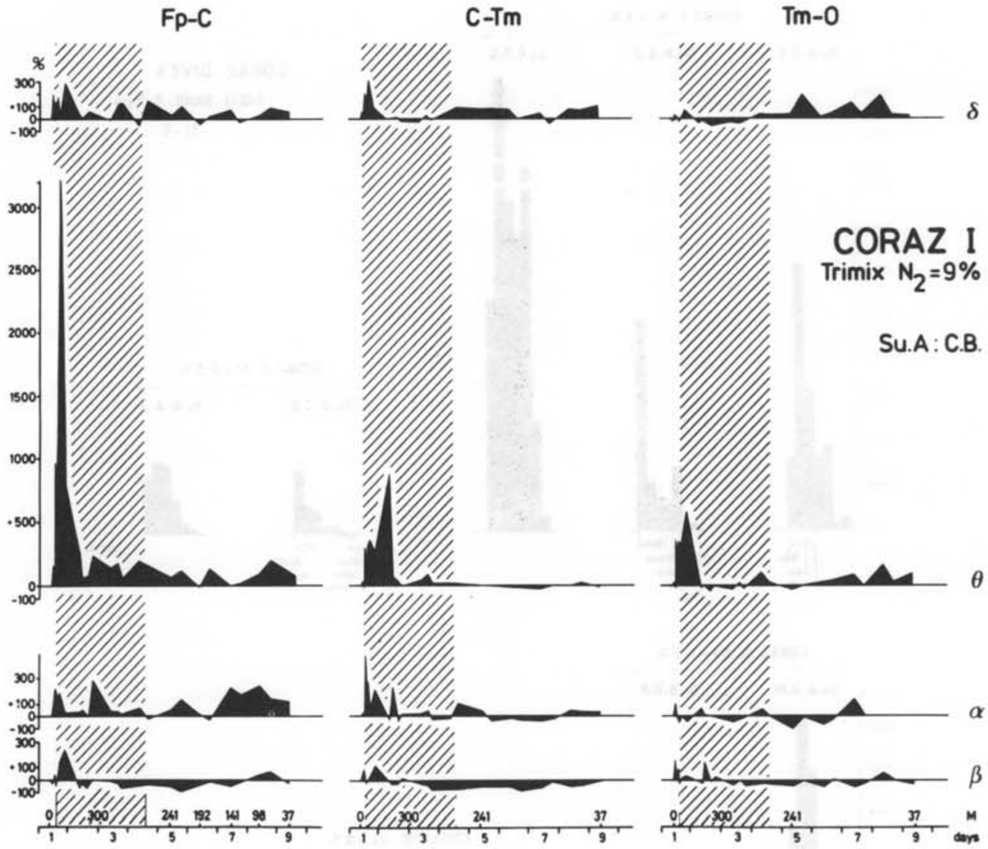

Fig. 6. Evolution of the EEG power spectra as a function of depth in Subject A during CORAZ I. The same derivations shown in Fig. 5 were utilized for the EEG analysis (Fp. C; C. Tm; Tm O). The four frequency bands were analyzed separately from top to bottom: 1–4 cps (delta), 4–7 cps (theta), 8–13 cps (alpha), 13–22 cps (beta). Evolution of power is presented from left to right for each frequency band and for each derivation; shaded portions represent stay at 300 m. *Ordinates:* increase expressed as percentage difference from control values. *Abscissae:* depths and days.

The amplitude of the more rapid activities (alpha and above all beta bands) was also higher on the frontal and/or central leads of the three subjects during the compression from 240 m, and during the first hours of stay at 300 m (maximum increase 300%). On the posterior lead, the amplitude of the alpha and theta bands showed an accentuation at the beginning of compression (+100%) then a decrease during the entire stay at the bottom (−60 to −70%).

The EEG modifications disappeared during the decompression between 100 and 80 m.

CORAZ II (N_2 = 4.5%). The EEG modifications described for CORAZ I were also found in Subjects A and B (Fig. 8).

Between 180 and 240 m, the first bursts of theta activity appeared on the central and frontal leads where they predominated. The power spectra of the theta band indicated an increase of 200% in Subject A and 400% in Subject B. (*Subject A:* Fp. C: +75%; C. Tm 190%; Tm. O −55%. *Subject B:* Fp. C: +360%; C. Tm +90%; Tm. O +36%.) The apparition of EEG patterns resembling stage 1 sleep a few seconds after closing the eyes was also seen. The

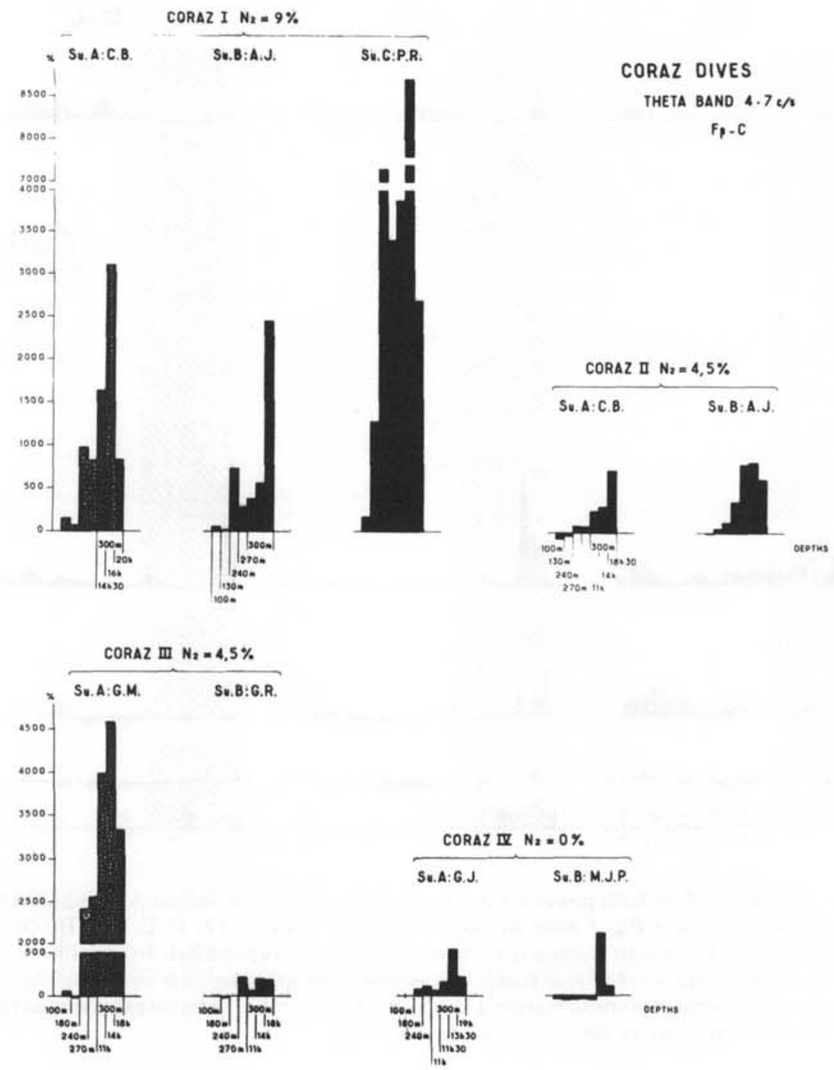

Fig. 7. Changes in EEG power spectra on theta band in fronto polar/central recording during the first day of the four dives. *Ordinates:* increase expressed as percentage difference from control values. *Abscissae:* depths and hours.

posterior alpha decreased in Subject B (−60%); in Subject A, the power spectra gave an increase of 100–200%.

At about 240 m in Subject A, and at 300 m in Subject B, EEG paroxysmal discharges appeared in the frontal lead.

During the stay at the bottom, these modifications became more pronounced over the first few hours. For the theta activity, this increase was about 700–900% in all the subjects 7 h after the end of compression (Fig. 7). (*Subject A:* Fp. C +725%; C. Tm +520%; Tm. O −40%. *Subject B:* Fp. C +810%; C. Tm +550%; Tm. O +300%.) An improvement of the EEG recording was observed on the second day of the dive; the EEG paroxysmal discharges disappeared in both subjects between the 20th and 24th h after arrival at the bottom. Theta

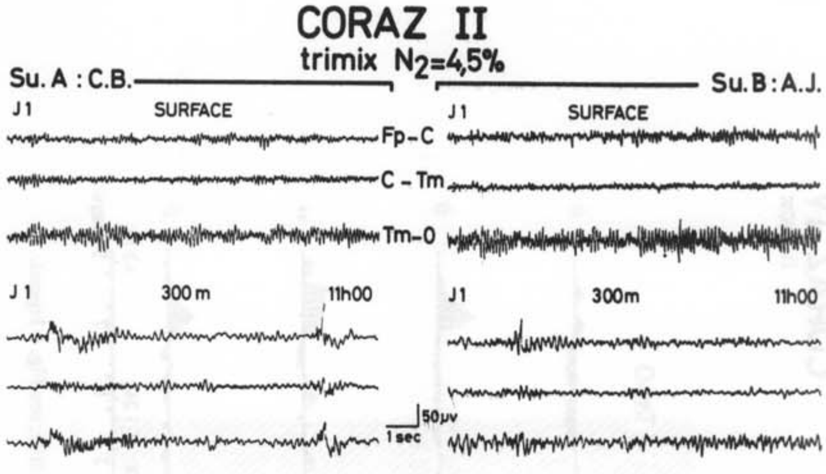

Fig. 8. Subjects A (left) and B (right) during CORAZ II. EEG with eyes closed at surface and at 300 m. J = day.

activity started to decrease from the 20th h but the return to normal activity occurred during the decompression between 130 and 100 m.

CORAZ III (N_2 = 4.5%). The EEG modifications were as follows: From 180 m alpha amplitude decreased in both subjects (−50 at −60%). Between 180 and 240 m, bursts of theta activity appeared in the frontal and central leads for both subjects. They were much larger in Subject A than in Subject B, between 240 and 300 m (Fig. 7). (*Subject A:* Fp. C +4000%; C. Tm. +1300%; Tm. O −50%. *Subject B:* Fp. C +220%; C. Tm +68%; Tm. O −50%.)

From 180 m onwards in Subject A and 300 m in Subject B, EEG patterns resembling stage 1 sleep appeared after closing the eyes. They were less frequent in Subject B. There were no EEG paroxysmal discharges. The EEG modifications became more pronounced during the first hours of the stay at the bottom (an increase in theta activity of 4600% in Subject A and about 300% in Subject B was recorded 3 h after the end of compression). (*Subject* A: Fp. C +4600%; C. Tm +2600%; Tm. O +40%. *Subject* B: Fp. C +240%; C. Tm +100%; Tm. O −30%.) These values started to decrease 20 h after arrival at the bottom. The return to normal was seen during decompression at about 100 m.

CORAZ IV (N_2 = 0%). The EEG modifications were very small and were characterized by the following elements (Fig. 7):

From 100 m, the alpha posterior amplitude decreased in both subjects (−30 to −50%).

From 240 m onward there was a slight accentuation of theta activity in both subjects in the frontal and central leads. This activity increased during the compression from 240 to 300 m but remained relatively small. (*Subject* A: Fp. C +100%; C. Tm +70%; Tm. O −40%. *Subject* B: Fp. C −40%; C. Tm +30%; Tm. O −50%.) There was also an increase of the power of delta activity in Subject A (Fig. 9) (Fp. C +380%; C. Tm +300%; Tm. O +30%). The theta activity continued to develop during the first hours of the stay at the bottom. The power spectra showed an approximate 500% increase in theta activity in Subject A 3 h after the end of compression and 700% in Subject B (Fig. 9). (*Subject* A: Fp. C +546%; C. Tm +480%; Tm. O +100%; *Subject* B: Fp. C +728%; C. Tm +57%; Tm. O +34%.) In Subject A, the power of

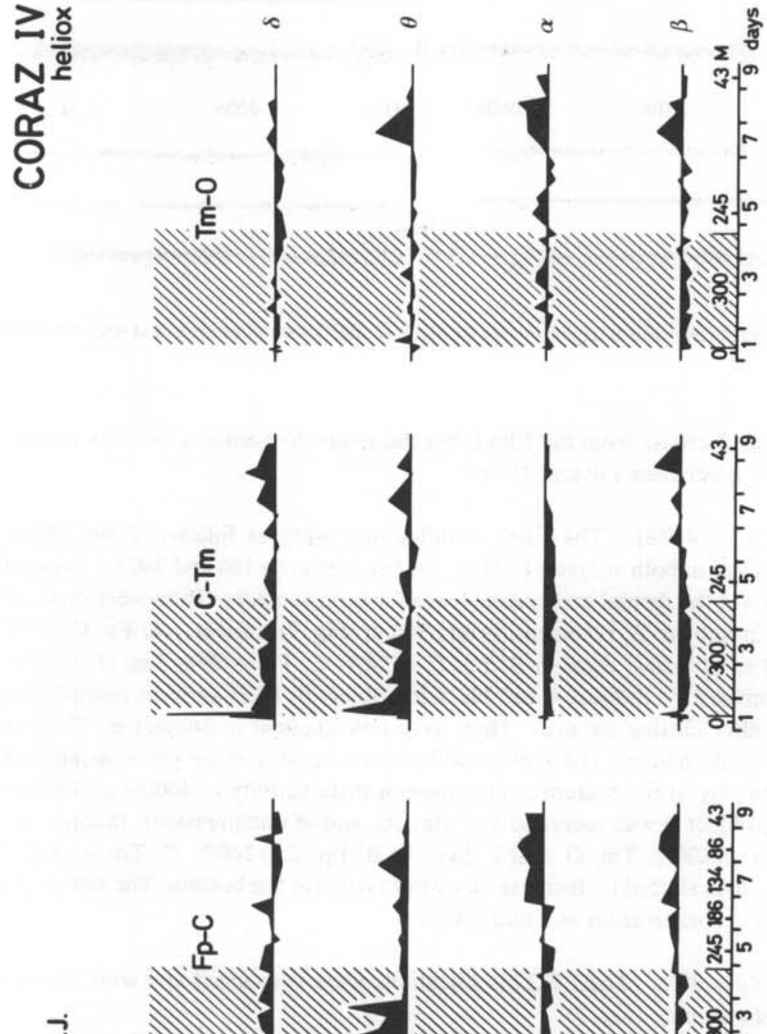

Fig. 9. Changes EEG power spectra as a function of depth for Subject A in CORAZ IV dive; see Fig. 6 legend.

delta activity decreased. From the second day, theta activity decreased during the stay, but the return to normal EEG was found at about 160 m during the decompression. During the dive, the subjects showed neither EEG paroxysmal discharges nor sleep-like EEG patterns during the day.

Clinical symptoms: dives to 180 m

Tremor

In all the cases, the five subjects showed no significant increase in tremor (dives He-O_2 or He-N_2-O_2, 10 and 20% N_2).

Dysmetria

There were no apparent signs of dysmetria.

Other behavioral disturbances: dives to 180 m

All of the divers were in satisfactory condition and able to carry out the work.

EEG symptoms: dives to 180 m

The experiments in He-O_2 and He-N_2-O_2 allowed us to distinguish three groups of divers (Table 4, Fig. 10).

Subjects of the first group showed EEG modifications (an important increase in theta activity on the frontal and/or central leads) with the mixtures He-O_2 and He-N_2-O_2 (Subjects COM and MAR). The second group showed little or no EEG modifications with the He-O_2 mixture, but each subject had significant increase in the theta activity with the He-N_2-O_2 mixture (subjects PAN and MOR). The diver representing the third group showed no significant EEG modification with any of the breathing mixtures (Subject BUL).

DISCUSSION

The results obtained during various dives allowed us to make comparisons among the different mixtures. Even though some of these observations were made on different subjects during the series CORAZ (the differences in individual sensitivity had been well known [3, 6, 9, 10, 15, 16]), certain information was established.

Clinical observations

At 300-m depth, dysmetria was more pronounced with the mixture He-O_2. Lassitude and fatigue were found with the various mixtures (He-O_2 and He-N_2-O_2). Behavioral modifications (euphoria, drowsiness, loss of interest in the work to be accomplished) were more evident in the mixtures containing nitrogen. The intensity of the tremor was similar in the dives with 4.5% or 0% of N_2 and depended on the individual sensitivity to HPNS. With 9% N_2 the tremor tended to be less than at the surface.

Most of these symptoms appeared worse upon arrival at the bottom, but they decreased rapidly when the mixture contained N_2.

TABLE 4

EEG ACTIVITIES OF THETA FREQUENCY BAND: PERCENTAGE OF DIFFERENCE BETWEEN SURFACE AND 180 M

Subject	$He-O_2$	$He-N_2-O_2$ (10% N_2)	$He-N_2-O_2$ (20% N_2)
MAR	+ 280	—	+ 400
COM	+ 780	+ 560	—
PAN	+ 21	+ 900	—
BUL	+ 6	+ 30	+ 40
MOR	+ 50	—	+ 400

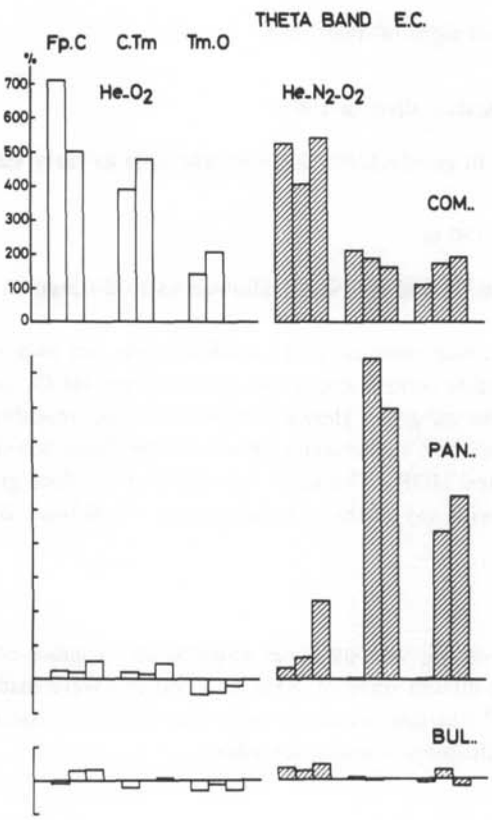

Fig. 10. Evolution of the power of EEG activities of the theta band frequency expressed in percentage of difference with respect to the mean value of surface. Three subjects are represented from top to bottom. For each subject, results obtained with the $He-O_2$ mixture have been regrouped on the left-hand graph; the graph on the right shows results obtained with $He-N_2-O_2$ (N_2 = 10%). On each graph the variations are shown: Fp. C on the left, C. Tm in the middle, and Tm. O on the right. The evolution is represented for the different tests affected at 180 m (beginning, middle, and end of stay). Surface level is 0%.

$$\frac{(Vp - Vs)}{Vs} \times 100.$$

At 180-m depth, the clinical symptoms were only slight; a fact that must be considered in relation to the depth. There was no significant difference between the He-O_2 and the He-N_2-O_2 mixtures.

EEG observations

At 300-m depth, the EEG modifications usually described with He-O_2 mixtures between 180 and 300 m were present and even greater in the presence of 4.5% or 9% N_2 in the most divers. At 300 m the increase of theta activity was very high; it reached and exceeded 1000%. On the contrary, with the He-O_2 mixture the EEG modifications were less noticeable and the increase in the theta activity did not exceed 800%.

Furthermore, with 4.5 or 9% N_2 in He-O_2 certain subjects showed paroxysmal discharges whose significance is unknown. The problem is to determine if these modifications are brought on by the rapid compression or a given quantity of N_2, or both. During the rapid compressions conducted to depths of 300 to 365 m (PHYSALIE I to IV) (2, 3), no modification of this type was observed. In general, such paroxysmal discharges were not evident in the compressions that were conducted previously in a He-O_2 mixture to 610 m (6, 9, 10). It should be noted that the two subjects who showed these paroxysmal discharges in this experimental series were compressed to 610 m with a He-O_2 mixture without any such EEG modifications (10). Consequently, we believe these reactions are related to the use of the He-N_2-O_2 mixture, but their significance has yet to be determined.

Interindividual differences are just as appreciable when subjects breathe both He-O_2 and He-N_2-O_2, which confirms the variability of individual sensitivity to HPNS, as has already been observed during various simulated dives (3, 6, 9, 10, 13, 15, 17). Therefore, we should make certain reservations in the interpretations of the modifications observed at the level of each group of divers during the various dives. It is important to note that the same two divers had less important EEG modifications with 4.5% N_2 than with 9% N_2, and that a diver (Subject B of CORAZ III) had fewer EEG modifications with 4.5% N_2 than the two divers who had no nitrogen.

In all cases, the EEG modifications increased even after the end of compression and reached their maximum between the 3rd and the 7th h at the bottom. The decrease in the EEG alterations or the disappearance of paroxysmal discharges or both occurred, depending on the individual, between the 10th and 24th h spent at 300 m. However, improvement in the subjects' behavior appeared after approximately 4 h stay at the bottom. Most of them were able to work effectively in water, and the results of their psychometric tests were better than those measured at the beginning of the stay (18). According to these authors (18), the recuperation is more appreciable when the mixture contains nitrogen. The decrease of EEG modifications is more visible with the He-N_2-O_2 mixture.

At 180-m depth, the dives in He-O_2 and He-N_2-O_2 mixtures demonstrate the interindividual differences of the reactivity of the EEG. In certain subjects there exists a homogeneity if one considers the appearance of the theta activities with all the breathing mixtures. This is true for three out of five subjects: two subjects always presented important modifications with the two types of mixtures; one subject never showed modifications. Two other subjects showed important variations between the two types of mixtures: the theta activities were more important at 180 m with the He-N_2-O_2 mixture in comparison to the He-O_2 mixture at the same depth.

Of course, a depth of 180 m is relatively slight compared to that of 300 m, and it is probable that the EEG modifications or the differences between the two mixtures would be greater at a greater depth.

GENERAL COMMENTS

The results obtained in our two experimental series are slightly different from those reported by Bennett et al. (13). In our conditions, it was the He-O_2 mixture that tended to give better results during compression and with respect to the He-N_2-O_2 mixture, whereas for Bennett et al. (13) the results with the He-N_2-O_2 mixture were better. It must be mentioned, however, that the experimental conditions of these authors differed from our own: the depth was the same (300 m) but the compression was faster (33 min) and the percentage of nitrogen was slightly higher (10%). In addition, the stay at the bottom was short; it has been shown elsewhere (19, 20) as well as in these CORAZ experiments that the HPNS and especially the EEG modifications develop with a certain latency and do not appear immediately after rapid compression.

The He-N_2-O_2 mixture seems to have a beneficial action on certain clinical symptoms. It lessens the tremor and the dysmetria, an effect which agrees with clinical observations by other authors (12, 13, 21, 22, 23). Nevertheless, it creates behavioral problems (euphoria, for example), and more important still, it increases drowsiness and in certain sensitive subjects accentuates the EEG modifications. This was the case with PAN at 180 meters (greater theta activity with He-N_2-O_2) and Subjects A and B at 300 meters in the CORAZ dives I and II (EEG modifications were greater with 9% N_2 than with 4.5%). Thus, there is a dissociation between the tremor and the EEG modifications, which already has been reported during experiments in an He-O_2 mixture (10). This dissociation could reveal the existence of mechanisms that are different at their origin. The tremor seems to be lessened by narcotic agents such as nitrogen, a finding which corresponds to the observations on the narcotic agent-pressure antagonism (22, 23, 24, 25, 26, 27). The EEG modifications would be hardly influenced or reinforced by the presence of nitrogen in the mixture. This could correspond to a positive pressure—narcotic agent association, which has been observed by various authors in certain biological or physiological functions (28, 29).

Recent experiments on the baboon Papio papio (19, 20, 30) and in man (31) tend to show that the action of nitrogen on the HPNS is complex. In these experiments, nitrogen added to the He-O_2 mixture at the beginning of compression did not lessen the HPNS, but rather increased it. On the other hand, it did lessen the HPNS when added during or at the end of compression. In these conditions, it seems difficult to explain the action of nitrogen by the sole hypothesis of pressure reversal effect and critical volume (23, 26).

From the results obtained during these experiments on 12 subjects, one can say that the HPNS observed with a He-N_2-O_2 mixture is not the same as that observed with a He-O_2 mixture. Consequently, HPNS is not a homogeneous entity, and different mixtures can produce different symptoms. Naturally, these differing combinations of symptoms have certain characteristics in common, which may be related to the method of compression or pressure, as has already been observed in the baboon Papio papio with a He-O_2 and H_2-O_2 mixtures (32, 33). The question should be asked whether the HPNS is a definable unit and/or whether in the future it will not be necessary to redefine it as a function of the given breathing mixtures and compression curves.

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Rostain JC, Gardette-Chauffour MC, Naquet R. Le SNHP au cours de compressions rapides chez l'homme respirant $He-O_2$ et $He-N_2-O_2$ à 300 m et 180 m de profondeur. Undersea Biomed Res 1980; 7(2):77–94.—Les effets de divers mélanges $He-N_2-O_2$ (N_2 = 9% et 4,5%) et du mélange $He-O_2$ ont été étudiés au cours de quatre plongées identiques à 300 m (durée de la compression = 4 heures). Des expériences complémentaires ont été réalisées à 180 m avec des mélanges $He-N_2-O_2$ (N_2 = 10% et 20%) et $He-O_2$ (durée de la compression : 15 min). Les résultats de ces plongées montrent que le tremblement est peu important et qu'il n'y a pas de différence entre les divers mélanges à 180 m et entre le mélange $He-N_2-O_2$ à 4,5% et $He-O_2$ à 300 m. En revanche, la présence des divers pourcentages d'azote dans le mélange $He-O_2$ n'empêche pas la survenue des modifications EEG à 180 m ou 300 m et leur intensité apparait aussi importante (et parfois même plus importante) qu'avec le mélange $He-O_2$. De plus à 300 m, avec le mélange $He-N_2-O_2$ certains sujets présentent des modifications EEG paroxystiques jamais observées avec le mélange $He-O_2$. Dans tous les cas, l'état physique des sujets ne leur permet pas de travailler à l'arrivée à 300 m ; un délai de 4 heures est nécessaire pour qu'ils puissent travailler correctement. Cette amélioration comportementale précède la régression des modifications EEG qui se situe entre la 10ème et la 14ème heure du séjour à 300 m. Ces résultats montrent que la présence d'azote réduit certains symptômes cliniques du SNHP mais elle n'améliore pas les tracés EEG et dans certains cas accentue les anomalies. Le mode d'action de l'azote apparait donc relativement complexe et des études complémentaires sont nécessaires pour trouver les meilleurs combinaisons entre méthodes de compression et composition du mélange.

SNHP
tremblement
système nerveux
hélium
EEG
pression
vitesse de compression
azote

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