INFLUENCE OF ASCENT RATE ON VENOUS BUBBLES DETECTED AFTER RECREATIONAL DIVES

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Ascent rate after dive is known for its importance in the risk of decompression sickness, but there is little data about it. It seems to be determined, in the different decompression tables, more by empiricism and intuition than by experimental studies or mathematical models.

Most of the decompression tables in the world present an ascent rate about 10 m/min.

The French decompression tables «Marine Nationale 1990» recommend to ascend at 17 m/min.

The French COMEX tables published in 1987 were the base of the tables «Ministère du travail 1992». They recommend an ascent rate between 9 and 15m/min.

Factors as age , weight, fat tissue, fitness or exercise are also known for their implication in the risk.

For 20 years, the ultrasound monitoring allows to estimate, during the decompression, the intensity of the gas phase and the probability of DCS (SAWATZKI & NISHI, 1991). BOVE & al. (1974) showed that a high grade of venous bubbles could increase the risk of spinal DCS.

The aim of our study was to better know the influence of ascent rate on the grades of venous bubbles. It was suggested by existing data (MARRONI & ZANINI, 1981, PILMANIS, 1990; VANN & THALMANN, 1993; POLLARD & al.,1995; MOON & al.,1995; SMITH & STAYTON, 1978; NEUMAN & al 1976, LANG & ERGSTROM, 1990, FRANCIS, 1990).

20 divers performed 52 dives in water, followed by ultrasonic detections of bubbles.

MATERIALS AND METHODS

Subjects

20 experienced male divers, mean age = 35.42 $\pm$ 11.57, mean weight = 78.85 $\pm$ 12.91.

(table1)

Dives

The divers performed twice the same dive, in one case ascending at 9m/min, in the other case at 17m/min.

The dives were of 2 types : 30min/30m and 25min/35m.

They were performed in real conditions, the divers swimming normally on the bottom.

The descent was done at 30-35m/min and its time was included in the bottom time.

The ascent rate was controled with chronometer and pressure gauge, and by means of a dive computer equipped with a bargraph measuring the ascent rate (Master Pro - Beuchat).

The ascent time to the first decompression stop was:

* 180 sec at 9m/min and 95 sec at 17m/min for the 30m dive (difference : 85 sec)
* 195 sec at 9m/min and 102 sec at 17m/min for the 35m dive (difference : 93 sec)

The decompression stops were those of the COMEX tables 1987 :

* 10 minutes at 3 meters for the 30m dive
* 3 minutes at 6 meters and 15 minutes at 3 meters at 3 meters for the 35m dive.

The dives were carried out in Marseille between october 1995 and april 1996, so the conditions of weather, sea and temperature were variable during this period.

Table 1 : Characteristics of the divers

N°	*Age*	*Weight*	*N°*	*Age*	*Weight*
1	47	78	11	41	104
2	54	92	12	37	105
3	47	85	13	28	65
4	30	67	14	47	82
5	26	75	15	26	80
6	32	74	16	45	89
7	53	69	17	26	68
8	45	85	18	20	70
9	48	93	19	26	64
10	19	72	20	23	60

The subjects hadn't dived 12 hours before each dive , they performed one of the two types of dive, but n° 6, 7, 11 the 2 types. N° 6 and 16 performed twice the 35m dive.

bubble detection

It was performed by echocardiography and pulsated doppler in the department of cardiology of the La Timone Hospital in Marseille, by means of a « WINGMED CFM 750 A » Diasonics, equipped with a probe of 3,5 Mhz. We used this method to resolve the problem of the « no-echogenicity » of some subjects, using the classical continouus doppler.

The delay from the site of the dives to the hospital was about 1 hour, so, the detections were performed between 1h. and 1h.15 min. after the dives.

Some detections were made between 1h 15 and 1h 30 after the dive:

subjects : n° 9 (17m/min), n° 14 (17 m/min), n° 5 (17m:min), n° 3 (9m/min).

The Spencer scale was used to evaluate the signals of bubbles because we had seen that, if the echography allowed to detect the site of the bubbles in the right ventricle, the pulsated doppler allowed to determine the grade of the bubble signals.

The interpretation of the signals was carried out by an experienced operator who didn't know the parameters of the dives.

Spencer scale

- Grade 0 : Complete lack of bubble signals

- Grade 1: Occasional bubble signal, with the majority of cardiac cycles free of bubbles

- Grade 2: Many, but less than half of the cardiac cycles contain bubble signals, singly or in groups

- Grade 3: All of the cardiac cycles contain bubble signals, but not overrinding the cardiac signals

- Grade 4: Bubble signals sounding continuously throughout systole and diastole of every cardiac cycle, and overrriding the normal cardiac signals

We also performed detections by the classical means of the continuous doppler to check if the two methods were equivalent.For this, we used a DUG « COMEX PRO » equipped with a probe of 5 Mhz. We realized that many subjects, because of their anatomy, had a bad cardiac signal in a standing position. So, we performed the continuous doppler monitoring in left lateral decubitus, which position permitted for most subjects a better signal. The probe was placed in the precordial region.
All the detections were video and audio recorded .
For statistical significance, we used the test T of Wilcoxon for ascent rate. Because bubble production is dependent from several factors, we included ascent rate, age and weight together in a multiple linear regression. Significance was taken at $P < 0.05$.
Moreover, to emphazise the effect of age and weight on bubble production, we divided the subjects in 2 groups for : age > 40 and age < 40, and for weight > 75 and weight £ 75.
We made the average of the results for each subject, and divided them in 2 categories: bubble producers (B.P.): average ³ 2 and no bubble producers: average < 2.
Then, we determined the percentage of bubble producers in each group.

RESULTS

Table 2 shows the grades of bubbles for all the dives.
Table 3 shows the comparison between pulsated doppler and continuous doppler.
The effect of ascent rate was significant (test T of Wilcoxon) for the 28 dives at 35 m. ($p < 0.05$) but not for the 24 dives at 30 m. ($p = 0.5$)
The multiple linear regression shows the significativity of weight ($p < 0.0001$), age ($p = 0.0116$); ascent rate, with $p = 0.0775$ is at the limit of significativity.
There were 7 B.P./ 20 subjects (Table 4). They were divided in the following way:

* age > 40 : 6 B.P./9 subjects → 66.6 %
* age < 40 : 1 B.P./11 " → 9.1 %
* weight > 75 : 7 B.P./10 " → 70 %
* weight ≤ 75 : 0 B.P./10 " → 0 %

Table 2 : results for all dives

Subject n°	*9m/min*	*17m/min*	*subject n°*	*9m/min*	*17m/min*
1 (35m)	0	1	10 (30m)	1	0
2 (30m)	3	3	11 (35m)	1	3
3 (35m)	2	3	11 (30m)	4	4
3 (30m)	3	3	12 (30m)	3	3
4 (30m)	0	0	13 (35m)	0	0
5 (30m)	0	1	14 (30m)	1	3
6 (35m)	0	2	15 (35m)	0	2
6 (35m)	1	1	16 (35m)	3	3
6 (30m)	1	1	16 (35m)	3	3
7 (35m)	0	0	17 (35m)	0	0
7 (30m)	2	1	18 (35m)	0	0
8 (30m)	3	3	19 (35m)	0	0
9 (30m)	1	2	20 (35m)	0	0

Table 3 : Comparison : pulsated doppler/continuous doppler

Subject n°	*pulsated*	*continuous*	*Subject n°*	*pulsated*	*continuous*
6	1	0	17	0	0
6	1	0	17	0	0
7	1	1	11	4	4
8	3	3	18	0	0
10	1	0	18	0	1
12	3	3	19	0	1
14	2	3	19	0	0
16	3	3	20	0	0
16	3	3	20	0	0

Table 4 : Bubble producers

Subject n°	*age*	*weight*	*mean grade*
2	54	92	3
3	47	85	2.75
8	45	93	3
11	41	104	3
12	37	105	3
14	47	82	2
16	46	89	3

DISCUSSION

Our results are certainly biased by the nature of our study which required many conditions, such as the disponibility of all the participants (divers, medical personnel and department, dive boat, etc...), or the meteorological conditions.

So, the long period of its realisation didn't allow to standardize either the parameters of the dives or the physiological state of the divers.

Moreover, the choice of the method of detection made necessary the delay before the detections , so we made a « snapshot » of the bubbles flow about 1 hour after surfacing.

We didn't measure the kinetics of the bubbles as did MARRONI & ZANNINI (1981) who detected venous bubbles every 10 minuts until 40 minuts after surfacing.

For NISHI (1993), in most cases, bubbles peak about 1 hour after surfacing.

He recommends to conduce the monitoring within 20 min. after surfacing and to repeat the detections at 30-40 min. intervals for at least 2 hours.

Because of the conditions of the dives, the subjects had to exercise after surfacing: to go back up the boat, to undress and to put aside the equipment, to walk to the cars and inside the hospital. Consequently, we can assume that a large part of inert gas was eliminated before the moment of our detections.

Probably, the effect of ascent rate is not clearly significant, like in the study of MARRONI & ZANNINI, for this reason.

Moreover, we can assume that the significativity would have been better with more subjects and dives.

On the other hand, our results emphazise the effect of age and over all, weight.
This confirms the studies of GRAY (1951), LAM & YAU (1989) and CARLIOZ & al. (1985).
The echography coupled with pulsated doppler allowed a better detection than classical continuous doppler for all subjects, but it cannot be used at present on the dive boats for recreational diving. Continuous doppler remains the more operational method in real conditions of diving. It was equivalent to the pulsated doppler for the subjects who had a good echogenicity. The lying position on the left side of the subjects allowed to improve significantly the detections. Nevertheless, for several subjects having a bad echogenicity, it was impossible to detect the bubble signal by this method.

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