DECOMPRESSION PROFILES WITH DEEP STOPS: COMPARATIVE DOPPLER STUDY WITH THE PROCEDURES OF THE FRENCH NAVY.

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Background

French Navy uses since 1990 the MN90 table for air diving up to 60 meters. This table was developed according to a model of haldanian calculation, validated for the epidemiologic aspect with a total risk of accident of about 1 for 30000 dives. However this risk is not homogeneous and increases in the part of depth between 45 and 60 meters with 1 accident for 3000 dives (1). With an aim of optimizing the safety of these deepest incursions, French Navy evaluated two new protocols of decompression (protocols n° 1 and n° 2) with deep stops also calculated on a haldanian type of calculation (2).

Methods

Divers

12 military divers medically fit were selected. They set up a homogeneous group with an average age of 37.5 years, and approximately 10 years of seniority in the diving activities. 3 of them were before victims of decompression sickness, but these were minor accidents with fast recovery of the medical fitness for the diving. All the dives were performed in the wet part of a hyperbaric facility ; the divers had a moderate and controlled activity of fin swimming. Within the 48 hours before the dives, no physical exertion nor no dive were performed. Water was maintained at a constant temperature of 15° C.

Diving procedure

The protocol n°1 uses a slowed rate of ascent: 12 meters / minute instead of 15 meters / minute with the MN 90, with deep stops beginning around the half depth. From the first stop the rate of ascent is slowed down and passes to 3 meters / minute (instead of 6 meters / minutes with the MN 90). The total decompression time is longer than with the MN 90.
With the protocol n°1, 8 divers performed the following dives: 60 meters/20 minutes (table 1) and 2 successive dives 50 meters/15 minutes separated by a 3 hours surface interval (table 2). These dives were carried out twice by each diver by applying the procedure of the MN 90 then protocol n°1.

The protocol n°2 corresponds to the profile of the MN90 with integration of a two minute stop at the half-pressure, then again the decompression according to the MN 90 table.
With the protocol n°2, 8 divers tested only one profile of dive: 60 meters / 15 minutes according to same methods as the protocol n°1 (table 3).

Bubbles detection

The evaluation consisted on the detection of the venous circulating bubbles on the precordial area by two different Doppler methods: continuous Doppler DUG 5Mhz (3, 4) and pulsed Doppler 2 MHz (5) carried out by independent operators. The quotation of the bubbles level according to the model of Spencer was carried out every 30 minutes after the surfacing, during at least 2 hours (6). The bubble grades of the new procedures have been each time compared with those of the procedure of reference: the MN 90 table.
Spencer scale was used for both Doppler methods (7):
– grade 0: total lack of any bubble signal;
– grade 1: some sporadic bubble signals, but majority of heart cycles without;

– grade 2: occasional bubbles or in group in less than half the heart cycles;
– grade 3: at least one bubble every cycle, but they don't drown the normal heart noises;
– grade 4: continuous bubbling, drowning normal sound of heart.

Selected quotation corresponds to the bubble level persistent and stable during at least 10 systoles after sensitization manoeuvre (2 successive lower limbs flexions).

Statistic analysis
Comparison of the protocols with the reference table MN90 by Wilcoxon test applied to Doppler quotations to bubbles peak and by each Doppler technique.

Results
For all the dives, whatever the used Doppler detection technique, the maximum grade of bubbles (bubbles peak) is seen 60 minutes (T60) after surfacing. The protocol n°1 does not reduce the levels of bubbles compared to the table of reference MN90 (table 4), on the contrary the appearance of high and prolonged levels of bubbles during several hours concerning the successive dives (table 5), as well as the occurrence of a desaturation sickness of arthrological bend type led us to affirm the dangerousness of this procedure. So it has been decided to stop it. The protocol n°2, very close to MN90 table, does not improve either to a significant degree the levels of bubbles (table 6).

	MN 90	**Protocol n°1**
Ascent rate	15 $m.min^{-1}$	12 $m.min^{-1}$
Speed between stops	6 $m.min^{-1}$	3 $m.min^{-1}$
DEPTH of STOPS (m)	**STOPS (minutes)**	**STOPS (minutes)**
27		3 $m.min^{-1}$
24		1
21		1
18		2
15		2
12		4
9	3	6
6	8	9
3	32	22

Table 1: 60 m / 20 min dive

	Dive 1 MN 90	**Dive 2 MN 90**	**Dive 1 Protocol n°1**	**Dive 2 Protocol n°1**
Ascent rate	15 $m.min^{-1}$		12 $m.min^{-1}$	
Speed between stops	6 $m.min^{-1}$		3 $m.min^{-1}$	
DEPTH of STOPS (m)	**STOPS (minutes)**	**STOPS (minutes)**	**STOPS (minutes)**	**STOPS (minutes)**
18				
15				1
12			1	1
9		1	2	2
6	2	8	3	5
3	9	32	7	13

Table 2 : Successive dives 50 m / 15 min, with 3 h surface interval

	MN 90	Protocol n°2
Ascent rate	15 $m.min^{-1}$	15 $m.min^{-1}$
Speed between stops	6 $m.min^{-1}$	6 $m.min^{-1}$
DEPTH of STOPS (m)	**STOPS (minutes)**	**STOPS (minutes)**
25		2
9	1	1
6	4	4
3	19	19

Table 3: 60 m / 15 min dive

	MN90	MN90	Protocol n°1	Protocol n°1
doppler	DUG	PULSED	DUG	PULSED
Diver n°1	2	3	2	2
Diver n°2	2	2	1	1
Diver n°3	1	2	3	3
Diver n°4	1	3	2	3
Diver n°5	2	3	2	1
Diver n°6	3	2	3	1
Diver n°7	2	3	3	3
Diver n°8	2	3	3	3
Number of bubble scores	DUG	PULSED	DUG	PULSED
grade 0	0	0	0	0
grade 1	2	0	1	3
grade 2	5	3	3	1
grade 3	1	5	4	4

Table 4: Bubble score at T60 for a 60 m / 20 min dive
No significant difference (Wilcoxon tests) between the bubble score of the MN90 and the protocol n°1, whatever the method of Doppler detection.

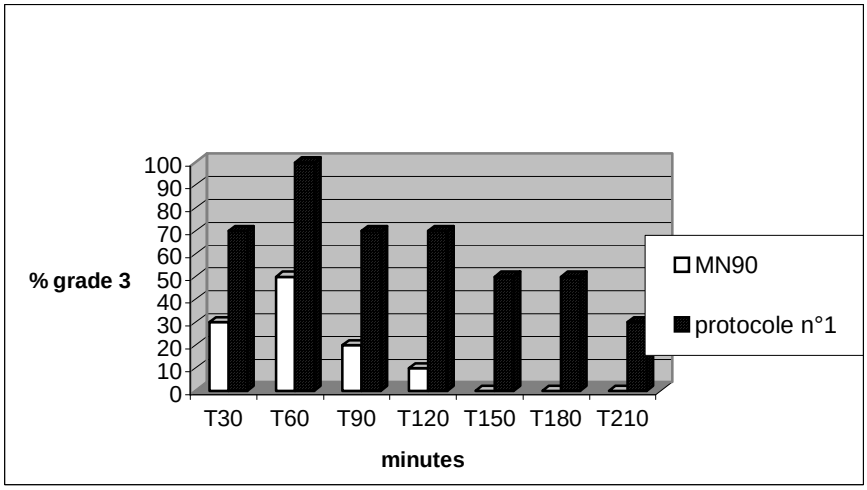

Table 5: Second dive to 50 m / 15 min (surf. int. 3 h): comparison MN90-Protocole 1.
Number of grade 3 detected with pulsed Doppler, in function of time after surfacing (min)

	MN90	MN90	Protocol n°2	Protocol n°2
DOPPLER	DUG	PULSED	DUG	PULSED
Diver n°1	1	1	1	1
Diver n°2	2	3	3	3
Diver n°3	1	1	1	1
Diver n°4	2	3	2	2
Diver n°5	1	2	1	2
Diver n°6	2	3	3	3
Diver n°7	3	3	3	3
Diver n°8	2	3	3	3
Number of bubble scores	DUG	PULSED	DUG	PULSED
Grade 0	0	0	0	0
Grade 1	3	2	3	2
Grade 2	4	1	1	2
Grade 3	1	5	4	4

Table 6: Highest bubble Grade at T60 after a 60 m / 15 min dive
No significant difference (Wilcoxon tests) between the levels of bubbles of the MN90 and the protocol n°2, whatever the method of Doppler detection.

Discussion

Whatever the used Doppler detection technique, it does exist a coherence of the results for comparison of the procedures. The protocol n°1 doesn't bring any benefit compared with the MN90 table, concerning bubbles grades for the dive 60m/20 min. One even mourns for a decompression sickness (arthrological bend). In the case of successive dives, bubble grades prolonged (more than 3 hours) were observed, concomitants with marked asthenia states. Those findings led to stop the protocol n°1.

The concept of deep stop remains attractive on the theoretical aspect for supposing the neutralisation of bubbles at their beginning stage (8). But the too important slowing down during the ascent and the standstill at too important depths contribute to extend the saturation; so it's no astonishing at noting prolonged bubbles grades after such a dive.

Just balance was not found with this protocol. Perhaps it does integrate too slow ascent rates, or it is an inadequate distribution of the stops, favouring in excess the deepest stops, to the detriment of the shallow stops. In order to take in account these results, a second protocol was made.

Protocol n°2, very close to MN90 table, integrated a single deep stop, short (2 minutes), at half pressure, and the remainder of the profile was not changed. Neither this approach did give results, with bubbles grades comparable to reference table MN90.

Conclusion

This study confirmed the validity of MN90 table in term of bubble scale.

Two procedures of decompression integrating deep stops didn't prove a benefit compared to the MN 90 table, "traditional" table of haldanien model.

The concept of deep stops in human decompression is worth to be confirmed for air diving (9).

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