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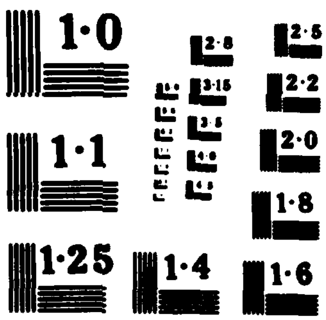
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AIR AND NITROX SATURATION DECOMPRESSION:

A report of 4 schedules and 74 subjects

by

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RUNNING HEAD: Nitrox saturation decompression

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ABSTRACT

Seventy-four subjects were decompressed from air or nitrogen-oxygen saturation exposures at 60 to 132 feet sea water gauge (fswg) using four different decompression schedules. A twenty hour schedule for decompression from an air saturation-excursion profile at 60 fswg resulted in pain-only decompression sickness (DCS) symptoms in two of twenty-three subjects. A thirty-two hour schedule from a different air saturation profile at 65 and 75 fswg resulted in DCS symptoms in one of twenty-four subjects. A third and fourth schedule for air or nitrox saturation at 132 fswg resulted in DCS symptoms in three of twelve and one of fifteen respectively. No serious (type II) symptoms were observed as a result of any of the exposures. All cases consisted of knee pain occurring either in the last 10 fsw of the decompression, or shortly after surfacing. Doppler ultrasound monitoring revealed venous gas emboli (VGE) in several subjects, but generally only shallow to 20 fswg. Results demonstrate an overall DCS incidence of 9.5%, and all cases were pain-only in character. Thus, the timing and character of DCS from air and nitrogen-oxygen saturation exposures is similar to that of helium exposures. Although differentiation between the presented schedules is impossible due to the limited number of subjects in each, the results suggest that the shallow ascent rate is more important in determining DCS incidence than that from deeper portions of the schedule.

INDEX TERMS: diving; humans; decompression; inert gas; saturation

INTRODUCTION

A confusing array of decompression schedules for saturation on air at increased ambient pressure has been formulated and tested over the past twenty years (1-9). The incidence of decompression sickness (DCS) has varied widely depending on individual susceptibility and characteristics of the particular exposure. Attempts to apply existing data to decompression schedule formulation have been complicated by different levels of exercise, temperature, carbon dioxide, oxygen and wet versus dry environments. Moreover, since much decompression information never reaches publication, subsequent analysis must rely on hearsay or inadequate data. To formulate sound schedules, and more thoroughly understand the physiology of saturation decompression, a large number of decompression trials with a variety of environmental conditions is required. To this end, this report is a detailed description of the conditions and results of air saturation decompressions occurring at this laboratory in the course of experiments over the past six years. This is not intended to be a comprehensive investigation into the theory and physiology of air saturation decompression, nor is it intended to promote the use of the described schedules. Rather, it is intended to add to the body of knowledge of how humans tolerate decompression from air saturation under a variety of conditions.

MATERIALS AND METHODS

Subjects

The subjects for these exposures were active duty or reserve Navy divers, with varying degrees of diving experience, and all of whom had been in hyperbaric chambers previously. No subject had been exposed to elevated pressure for at least two weeks preceeding the saturation exposure. Subject vital statistics for each series of experiments are shown in Table 1. No significant differences existed between the groups of subjects, with the exception that the AIRSAT 3 subject population was significantly older than that in AIRSAT 2. Informed consent was obtained prior to any exposures or procedures.

Facility

All saturation exposures were performed in the main hyperbaric chamber of the Environmental Simulation Facility located at the Naval Submarine Medical Research Laboratory in Groton, Ct. The chamber was of double lock design, steel construction and was man certified to 350 fswg. The diameter measured 9 feet, the inner lock being 15 feet in length and the outer 10 feet. Separate life support systems for each lock controlled CO_2, temperaure and humidity. CO_2 was monitored continuously in each lock by Beckman 864 analyzers and averaged 0.06 $\pm$ .02% for all exposures. Oxygen was monitored by Beckman 755 analyzers and was maintained at plus or minus 1% of the desired value by Teledyne 323 controllers. For clarification, the oxygen partial pressure profile for each of the exposures is shown in Fig.2. Temperature was adjusted to subject comfort and averaged 25.8 $\pm$ 0.9 degrees Celcius. All travel during decompression occurred in 1 fsw increments. Diet was not controlled or limited. Sleeping habits were generally not altered. Medications were discouraged and rarely used. Occasionally, acetaminophen, topical antifungal preparations, antacids, pseudoephedrine and topical decongestants were used. Analgesics were not administered during decompression. Activity levels generally consisted of unhurried movement about the chamber (exercise studies discussed below). Scientific procedures generally consisted of spirometry, other non-strenuous breathing tests, blood draws, special sensory tests (vision, hearing), psychomotor tests, EEGs, ECGs and the like. No oxygen breathing was included in any of the decompression schedules.

Decompression monitoring

Adequacy of decompression was gauged primarily by reported and elicited symptomatology. Symptoms were divided into conventional categories: pain only symptoms (type I) and multisystem or serious symptoms (type II), and treated according to guidelines detailed in the Navy Diving Manual (10). Occasionally the oxygen dose was modified when treating a subject with significant symptoms of pulmonary oxygen toxicity as a result of the saturation exposure. Precordial monitoring for right heart venous gas emboli (VGE) using doppler ultrasound was carried out at regular intervals during the decompression in schedules 2 and 4 only. A Sodelec D.U.G. unit with probe was used for the signal generation, and the Kisman-Masurel scoring scheme (11) was used for analysis of the signals. In this system, two scores are reported - one representing the VGE score with the subject standing at rest, and the other after a series of three deep knee bends (rest/movement).

SCHEDULE DESCRIPTION AND RESULTS

Schedule #1

The decompression schedule is shown in Table 3[1]. This schedule is based on the NOAA 3202 M-value matrix, assuming that the 480 minute half time tissue is the rate limiting compartment (2). This decompression was used for two series of air saturation exposures (AIRSAT 1 and 2), with a total of 23 subjects. The storage depth was 60 fswg, and daily excursions to 100 fswg or 150 fswg were made as shown in Fig.1A & B. Fifteen hours and 45 minutes elapsed between the 100 fswg excursions and 19 hrs and 20 min between the 150 fswg excursions. Each subject exercised on a bicycle ergometer for 30 minutes at approximately 75% of maximal capacity - pre-dive, on the excursions only during the dive, and post-dive. The final decompression began about 44 hours after the final excursion in AIRSAT 1 and 47 hours after the final excursion in AIRSAT 2. No symptoms resulted from any of the excursions in these experiments.

Twenty-three subjects decompressed from the above profiles using this schedule. One subject (AIRSAT 1) was classified as having type I decompression sickness. Briefly, this subject noted mild, deep seated right knee discomfort on awakening at 6 fswg, which then increased to moderate levels on reaching the surface. A similar pain had begun to appear in the left knee by the time recompression therapy was initiated (about 30 minutes after surfacing). Complete relief of the left knee discomfort and 90% relief of the right knee pain was achieved in the first 10 minutes of treatment. To minimize further oxygen stress, the second oxygen period at the 60 fsw level was eliminated, and the remainder of a standard U.S.Navy treatment table 5 (TT5) was completed. Complete relief of all symptoms with no recurrence was the final outcome.

One other subject (AIRSAT 2) reported a vague feeling of discomfort in the left knee about 3 hours after reaching the surface, but it resolved after several hours with no treatment. None of the other 21 subjects reported symptoms during or subsequent to the decompression. Doppler monitoring was not performed during this series.

Schedule #2

Schedule #2 was developed using the empirical relationship

$$R = k(PiO_2) \qquad (1)$$

where R is the rate of ascent in fsw/hr, PiO_2 is the inspired oxygen partial pressure in ATA, and k is 6. Since the breathing media for this schedule was air, the PiO_2 decreased as the depth decreased. To satisfy equation (1), the ascent rate also was reduced. For convenience, the ascent rate was reduced at 10 fsw intervals to the rate required by the lowest PiO_2 in the interval.

Schedule #2 was used for a series of eight exposures (the SUREX experiments), each with three subjects. The atmosphere was air throughout, and excursions to the surface were included (see Fig.1C & D). Further details of this exposure is contained in the references (12). The subjects spent a total of 44 hours at 65 fswg (SUREX 1-6), or 75 fswg (SUREX 7,8), and the decompression began about 20 hours after completion of the final ascending excursion. The excursions represented a significant decompression stress, and most subjects complained of pruritus and had detectable VGE during the surface interval. Four subjects had DCS symptoms (3 type I and 1 type II) during or immediately following the excursions. All subjects were asymptomatic prior to initiating the final decompression.

One of the twenty-four subjects (not one of the four with DCS symptoms during the excursions) noticed mild, deep seated left knee pain at about 2 fswg, which was essentially unchanged on arrival at the surface. Physical exam was entirely normal. A standard TT6 was initiated, and full relief was obtained after the first oxygen breathing period at 60 fswg. There was no recurrence.

The number of subjects with detectable VGE and the mean VGE score are shown in Table 3. In this schedule, no VGE were detected deeper than 10 fswg. The highest VGE score occurred in the subject with diagnosed decompression sickness (rest grade 2/movement grade 4). The other scores were generally very low.

Schedule #3

This decompression schedule used is the U.S. Navy standard helium-oxygen saturation decompression schedule (10). Because of the very low incidence of decompression sickness associated with the use of this schedule for shallow heliox exposures, it was believed that it might be sufficiently conservative to allow safe decompression from shallow air saturation exposures. The ascent rates are shown in Table 2. Rest stops are an integral part of this decompression. The protocol calls for rest stops (no travel) from 2400-0600 and from 1400-1600 independent of the starting time. Continuous travel occurs at all other times of the day.

This decompression was used exactly as indicated in a series of 4 identical air and nitrox saturation exposures (AIRSAT 3) each with three subjects. The pressurization and atmosphere profile is shown in Fig.1E. Briefly, daily 5 hour no-decompression excursions on air to 198 fswg (7 ATA) were made from a nitrogen-oxygen (PIO_2=0.30 ATA) storage depth of 132 fswg (5 ATA) on days 2,3 and 4. Eighteen hours and 45 minutes elapsed between the excursions. Twenty hours after the third and final excursion, and isobaric shift to air occurred. The air exposure at 5 ATA continued for 24 hours at which time the final decompression began (at 1000 on day 6). The chamber reached the surface at 1346 on day 8.

Three of the 12 subjects were classified as having type I DCS. All three had left knee discomfort, but the time of onset was somewhat different. Two of the three subjects initially noted symptoms at about the 5 fswg level, and the other subject noticed symptoms about 3 hours after surfacing. One of the two subjects noting symptoms while still under pressure was treated according to the minimal decompression concept (10) i.e.; recompressed 10 fswg deeper than where symptoms were noted, held for two hours while breathing 100% oxygen, and then resumed the decompression schedule. Full relief was obtained in this subject. The other subject with symptoms under pressure was allowed to surface (he did not mention symptoms until this time), and then treated with a modified TT5[2]. This subject had complete relief 5 minutes into the first oxygen period at 60 fswg, but he had a recurrence of the knee pain only thirty minutes after surfacing from the treatment. A modified TT6 then resulted in complete relief with no recurrence, and surprisingly, no further pulmonary symptomatology or decrement in pulmonary function. The subject with symptoms after surfacing was treated with a modified TT6, and had complete relief with no recurrence. Doppler monitoring was not performed during these exposures.

Schedule #4

This schedule was also derived using equation (1), with k equal to 5 instead of 6. This resulted in slower ascent rates, which were believed to be prudent as the subjects were expected to develop symptoms of pulmonary oxygen toxicity (see Fig. 2C). Animal studies have suggested that pulmonary oxygen toxicity reduces decompression tolerance (13). Slower ascent rates also appear to be necessary for deeper saturation exposures. This is discussed below.

The exposure for which this schedule was used (AIRSAT 4) is shown in Fig.1F. Briefly, compression to 132 fswg (5 ATA) on an atmosphere of nitrogen-oxygen (PiO_2=0.30 ATA) is followed, 12 hours later, by an isobaric shift to air (PiO_2=1.05 ATA). No excursions were performed. Forty-eight hours after the isobaric shift, another isobaric shift back to nitrox occurred (now PiO_2=0.50 ATA), and the decompression started immediately (at 2200 on day 3). The partial pressure of oxygen was maintained at 0.50 ATA until the chamber oxygen level reached 21% (at 46 fswg), afterwhich, the FiO_2 of 21% was maintained to the surface (decreasing PiO_2). The chamber reached the surface at 1508 on day 6.

Fifteen subjects have decompressed from the above profile using this schedule. One subject had onset of bilateral knee discomfort (left greater than right) on awakening on day 6 at about 10 fswg.

This discomfort would generally abate before the pressure was again reduced by 1 fsw (every 58 minutes at this point), at which time it would re-appear. This continued to about 2 fswg, where he was transferred to another chamber and treated with a standard USN TT5. He had rapid resolution of the pain at 60 fswg on oxygen, and no recurrence. The other subjects in the chamber were allowed to continue the schedule. The symptomatic subject had the highest VGE score of the three (rest-1/movement-3), but VGE were undetectable after completion of the TT5. The number of subjects with detectable VGE and the mean VGE scores are shown in Table 3 below. VGE were detected deeper in this schedule, with one subject having low scores at the 50 fswg level. It is interesting to note that in those subjects with detectable VGE, the scores did not generally increase as one neared the surface. In fact, some subject's VGE scores decreased from 10 fswg to the surface.

DISCUSSION

Meaningful comparison of these schedules is difficult due to the relatively small numbers of subjects and the well established variable nature of DCS. In fact, some investigators believe that decompression outcome can be well described by the binomial probability function (14). Therefore, suitable studies are difficult to perform. Nevertheless, this report constitutes the largest series of air saturation decompressions in the literature to date. Due to the increased use of air and other nitrogen-oxygen mixtures for saturation exposures and treatments, and the potential disabling nature of DCS, it is important to attempt differentiation between the schedules presented. This will allow concentration on potentially safer schedules in future research, rather than merely confirming that seemingly unsafe schedules are indeed, unsafe.

Therefore, it is instructive to examine each schedule in light of the theoretical tissue supersaturation acheived. In Table 4, the schedules are expressed as the mean delta-P[3] (supersaturation in atmospheres - ATM) in a single half time compartment (arbitrarily chosen as the 480 minute compartment) for the entire ascent[4]. Also, the delta-P in the same half time compartment is shown for the final 5-10 fswg of ascent[5] (surfacing delta-P). Also shown in Table 4 is the decompression sickness incidence, and overall mean ascent rate for each of the four schedules.

Of the indices listed in Table 4, only the surfacing delta-P appears to correlate reasonably well with the incidence of decompression sickness symptoms. The high incidence of DCS in schedule #3 may be explained by this comparison. While the mean delta-P for this schedule is similar to the others, the surfacing delta-P is more than twice as large as the largest of the other three. Furthermore, this value is twice that allowed for this tissue by accepted (although not well validated) computations of maximal tissue nitrogen tensions (M-values) (15). Surfacing delta-Ps for the other three schedules are within these limits. It also merits mention that the same schedule as #3 was used for a series of 60 fswg air saturation dives at another Naval laboratory, and likewise gave an unacceptably high incidence of DCS (personal communication, CDR E. Thalmann, NEDU, Panama City, FL). This effect of shallow ascent rates was also shown in a recently published report (16), where 5 of 6 subects had DCS symptoms after a 60 meter nitrogen-oxygen exposure. The mean delta-P was 0.41 ATM and the surfacing delta-P was 0.37 ATM. This point is by no means clear, however, as another recent nitogen-oxygen exposure to 165 fswg (17) had a 40% bends incidence (n=10) deep to 20 fswg, where the mean delta-P was 0.26 ATM. The surfacing delta-P was 0.33 ATM and another subject developed symptoms after surfacing. Also, the SCORE exposures (6), had a very low bends incidence (<5%) when the mean delta-P was 0.88 ATM and the surfacing delta-P, 0.43 ATM. The mean ascent rates and delta-Ps for any of the above exposures do not appear to correlate with the DCS incidence. Thus, until more data is available, reliable conclusions cannot be made. Nevertheless, the data presented here suggests that a significant slowing of the ascent rate should occur in the shallower portions (less than 20 fswg) of nitrogen-oxygen saturation decompression schedules. A reasonable goal appears to be a delta-P of about 0.5 - 0.75 ATM (480 minute compartment) for most of the decompression, gradually decreasing to about 0.20 ATM in the final 20 fsw. These conditions appear to be met by schedules #2 and #4, which gave the lowest incidence of DCS, but were also the longest.

Equation (1), from which schedules #2 and #4 were developed, is based upon a retrospective study of many saturation dives. An initial analysis of 579 helium oxygen man-decompressions indicated that the average safe rate of ascent increases linearly with the oxygen partial pressure (18). An extension of this analysis to 1179 helium-oxygen man-decompressions suggested that the average ascent rate also decreases as the saturation depth increases. Analysis of 160 man-decompressions from air or nitrogen-oxygen saturation dives indicated similar effects, but with slower ascent rates than those for helium. A recent nitrogen-oxygen exposure has also suggested that ascent rate must decrease as the saturation depth increases (17). Thus, the value of the constant k in equation (1) appears to depend upon both the depth of the saturation exposure and the inspired inert gas species.

Equation (1) appears to be a convenient empirical tool for developing saturation decompression schedules because it has only a single unknown. The schedule can be easily calculated on station, and if decompression sickness occurs, it can be made more conservative by reducing the magnitude of k.

Another factor to consider in the evaluation of these results is pulmonary oxygen toxicity. Data exists which suggests that pulmonary oxygen toxicity increases susceptibility to decompression sickness (13), although the mechanism remains unclear. It is possible that the presence of symptoms of pulmonary oxygen toxicity may have been partly responsible for the occurrence of DCS in these exposures. The degree of pulmonary oxygen toxicity in these exposures can be estimated from the forced vital capacity (FVC) measurement (19,20). Thus, one might expect that those subjects with DCS symptoms would have had greater decrements in the FVC than those without DCS symptoms. However, the FVC decrement of the five subjects with decompression symptoms in the AIRSAT exposures (the SUREX exposures represented a much lesser oxygen exposure) was not significantly different than those without symptoms. Nevertheless, it remains possible that pulmonary oxygen toxicity reduces decompression tolerance; the FVC may not be the pertinent index in this case.

Not only may pulmonary oxygen toxicity compromise decompression tolerance, it also may complicate treatment. Since current treatment regimens for decompression sickness call for the use of hyperbaric oxygen therapy, a pre-existing degree of pulmonary oxygen toxicity may compromise tolerance of the treatment itself. This was believed to account for an unusual case of pulmonary oxygen toxicity in at least one report (2), and was the basis for modifying the treatment tables used for the cases of decompression sickness described here. It appears, however, that subjects treated with hyperbaric oxygen for decompression sickness suffer no further decrement in pulmonary function. The 6 treated cases of decompression sickness in this report had no significant change in the FVC from before to immediately after the treatment (4.85 $\pm$ .57 L versus 4.99 $\pm$ .40 L). Thus, it appears that once recovery from the toxicity begins, the effect of an oxygen treatment table is minimal.

A further factor which complicates analysis of the results in schedule #3 is the timing of the rest periods. In the AIRSAT 3 experiments, the decompression was timed so that the subjects surfaced at 1345, or just prior to the 1400 rest stop. Therefore, the subjects were traveling at the 3 feet/hr rate since 0600, from about 22 fswg all the way to the surface. Should things have been timed so that the 2400-0600 rest stop occurred between 10 fswg and the surface, the results of this schedule may have been very different. It seems reasonable that rest stops should be in relationship to depth rather than the time of the day.

The character and timing of decompression symptoms seen in this series is similar to experiences with shallow helium-oxygen exposures (21,22). Most symptoms began while still under pressure, and the knee appears to be the most common site, indeed the only site in this series. In one reported helium-oxygen decompression series, knee pain accounted for approximately 80% of all symptoms resulting from the saturation decompression. Other symptoms commonly associated with deeper helium-oxygen saturation exposures (23), such as vestibular symptoms, were not observed in this series.

Sufficient precordial doppler monitoring for VGE was not performed to allow correlation with symptoms. However, the only subjects with type I DCS from schedules #2 and #4 also had the highest VGE score for those schedules. Overall, quantities of VGE were very low, and rarely present deeper than 20 fswg in any of the schedules. The deeper exposures had a tendency to produce detectable VGE earlier, as would be expected.

In conclusion, seven cases of decompression sickness out of 74 decompressions from nitrogen-oxygen saturation exposures at depths of 60 to 132 fswg are described in detail. Aside from the overall DCS incidence rate of 9.5%, meaningful conclusions are impossible to make in light of the statistically insufficient number of subjects. However, the data appear to suggest that the shallow ascent rates are more important in determining DCS incidence than those in the deeper portions of the decompression. Furthermore, decompression sickness in these nitrogen-oxygen saturation exposures is similar in character and timing with that of helium-oxygen exposures. Many more decompressions, using uniform, uncomplicated criteria and procedures, will be necessary before sound concepts of decompression can be formulated.

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FIGURE LEGENDS

1. Pressurization profile for all the exposures described in this report. A: AIRSAT 1 (schedule #1), B: AIRSAT 2 (schedule #2), C: SUREX 1-6 (schedule #2), D: SUREX 7,8 (schedule #2), E: AIRSAT 3 (schedule #3), F: AIRSAT 4 (schedule #4). Clear areas represent air as the breathing media, and shaded areas represent other nitrogen oxygen mixtures; lines - 0.30 ATA oxygen, balance nitrogen; dots - 0.50 ATA oxygen, balance nitrogen.

2. Oxygen partial pressure profiles for the exposures shown in the previous figure. A: AIRSAT 1&2 (AIRSAT 2 in broken lines), B: AIRSAT 3, C: AIRSAT 4, D: SUREX 1-8 (SUREX 7&8 in broken lines).

FOOTNOTES

1. This schedule is the same one used for the Shallow Habitat Air Dive experiment (9), with the arbitrary 8 hour sleep hold at 12 fswg deleted.

2. Modified by shortening the length of the oxygen exposure because of encumbent symptoms of pulmonary oxygen toxicity. For instance: the subject treated with the modified TT5 had an entire twenty minute oxygen breathing period eliminated from both the 60 and 30 fswg stages. The TT6 had shortened oxygen breathing periods, and lengthened air periods.

3. This calculation is based on the equation:

$$\text{Delta-P} = \text{ascent rate}/((0.693/T_{1/2})(60)) - PiO_2$$

where PiO_2 is the inspired oxygen partial pressure in ATA, delta-P is the tissue supersaturation in ATM, $T_{1/2}$ is the tissue compartment equilibration half time in minutes (480 in this report), and the ascent rate is in ATM/hour (ft/hr obtained by multipying by 33).

4. The mean delta-P for the entire ascent is calculated using the

mean ascent rates from Table 4 and a time weighted average PiO_2 for the entire ascent.

5. The surfacing delta-P is based on the ascent rates for the final 10 fsw, and a PiO2 of 0.21 ATA (surface value).

TABLE 1

SUBJECT VITAL STATISTICS*

EXPERIMENT	N	AGE (yr)	HEIGHT (cm)	WEIGHT (Kg)	BODY FAT (%)
AIRSAT 1	11	25.5±5.0	178±4.0	77.6±7.0	19.8±4.5
(schedule #1)		(20-35)	(172-185)	(69.9-91.2)	(14.9-28.0)
AIRSAT 2	12	23.8±3.3	180±8.0	77.3±9.0	16.4±3.6
(schedule #1)		(21-32)	(162-189)	(61.7-95.7)	(11.0-22.0)
SUREX	24	26±5.0	175±6.5	75.8±8.6	13.3±4.4
(schedule #2)		(20-38)	(164-191)	(56.5-94.8)	(6.5-24.6)
AIRSAT 3	12	30.1±3.6	176±9.0	81.4±10.0	22.1±4.3
(schedule #3)		(25-36)	(162-194)	(68.4-104.4)	(15.0-27.0)
AIRSAT 4	15	28.5±6.8	175±7.8	79.6±10.7	14.3±5.4
(schedule #4)		(19-39)	(160-186)	(62-107)	(7.6-28.7)

* - units expressed as mean ± standard deviation, (range).

TABLE #2

SCHEDULES

1		2		3		4	
DEPTHS*	RATE**	DEPTHS	RATE	DEPTHS	RATE	DEPTHS	RATE
60-45	10	75-70	15	132-100	12	132-50	24**
45-20	15	70-60	17	100- 50	15	50-40	26
20- 5	33	60-50	19	50- 0	20	40-30	30
5- 0	36	50-40	22			30-20	36
		40-30	25			20-10	44
		30-20	30			10- 0	58
		20-10	37				
		10- 0	48				
TOTAL		32:06****					
TIME 20:00		34:46		51:42		65:08	

Notes:

* In feet sea water gauge (fswg).

** In minutes per fsw.

*** Constant PiO2 of 0.50 ATA for this interval.

**** Total time for schedule from 65 fswg.

TABLE #3

VENOUS GAS EMBOLI ON ASCENT

	Depth (fswg)					
	50	30	20	10	5	0
SCHEDULE #2						
No. subjects with VGE	0	0	0	1	5	5
Mean VGE score	0/0	0/0	0/0	0/1	.4/1.9	.4/2
SCHEDULE #4						
No. subjects with VGE	1	2	3	3	-	3*
Mean VGE score	0/1	0.5/1	0.7/2	0.3/1.4	-	.7/2.1

* The one subject with DCS (see text) was treated before surfacing, and had no detectable VGE after the treatment.

TABLE #4

SCHEDULE CHARACTERISTICS AND RESULTS

SCHEDULE	MEAN ASCENT RATE FSW/HR	DELTA-P* (T1/2=480) MEAN	SURFACING	NO. SUBJECTS	DCS SYMPTOM
1(AIRSAT 1&2)	3.00	0.70	0.38	23	2 (8.7%)
2(SUREX 1-8)	2.02	0.34	0.23	24	1 (4.2%)
3(AIRSAT 3)	2.56	0.32	0.84	12	3 (25%)
4(AIRSAT 4)	2.03	0.29	0.16	15	1 (6.7%)

* - Units are atmospheres (ATM)

Figure 1

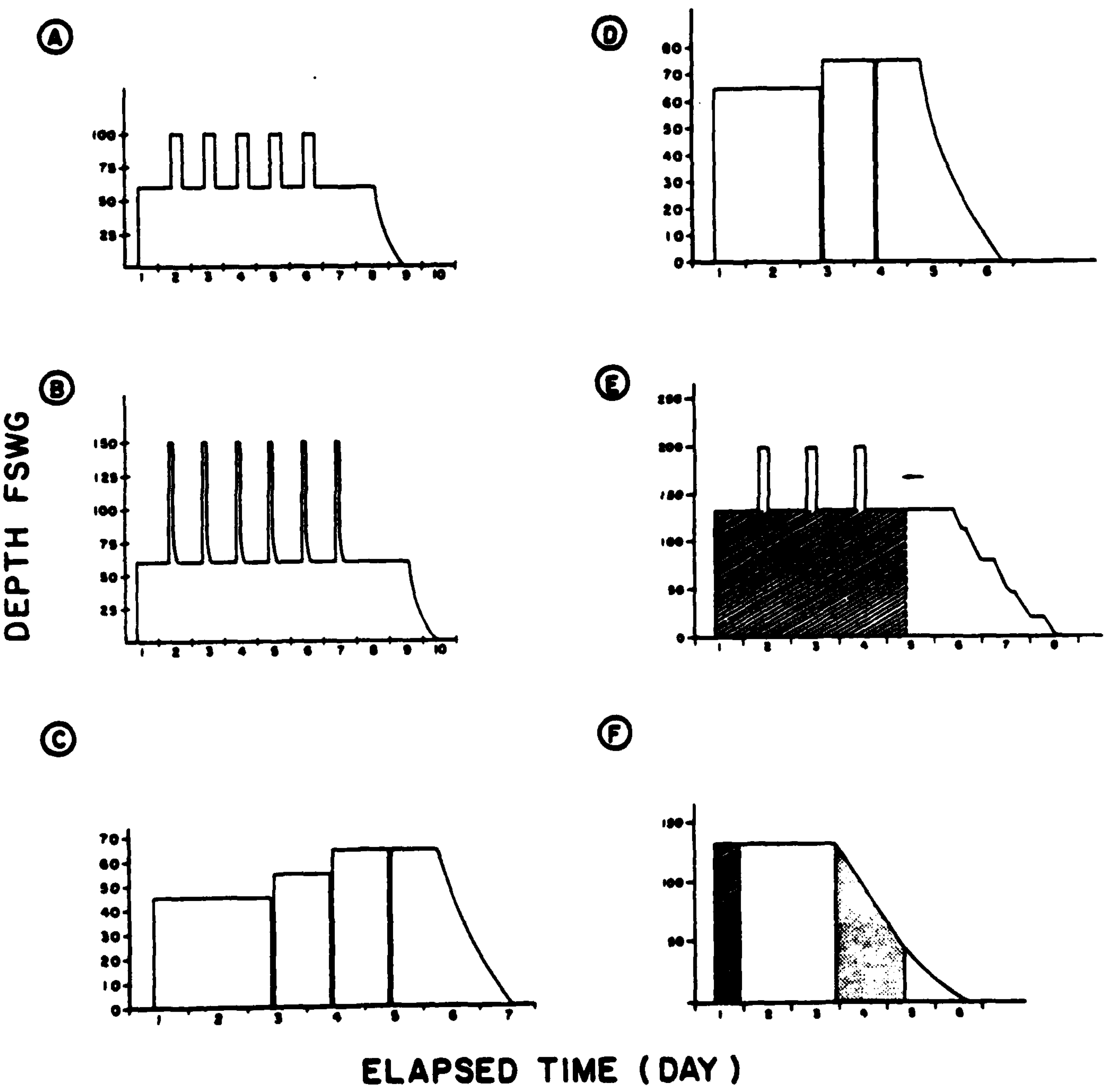
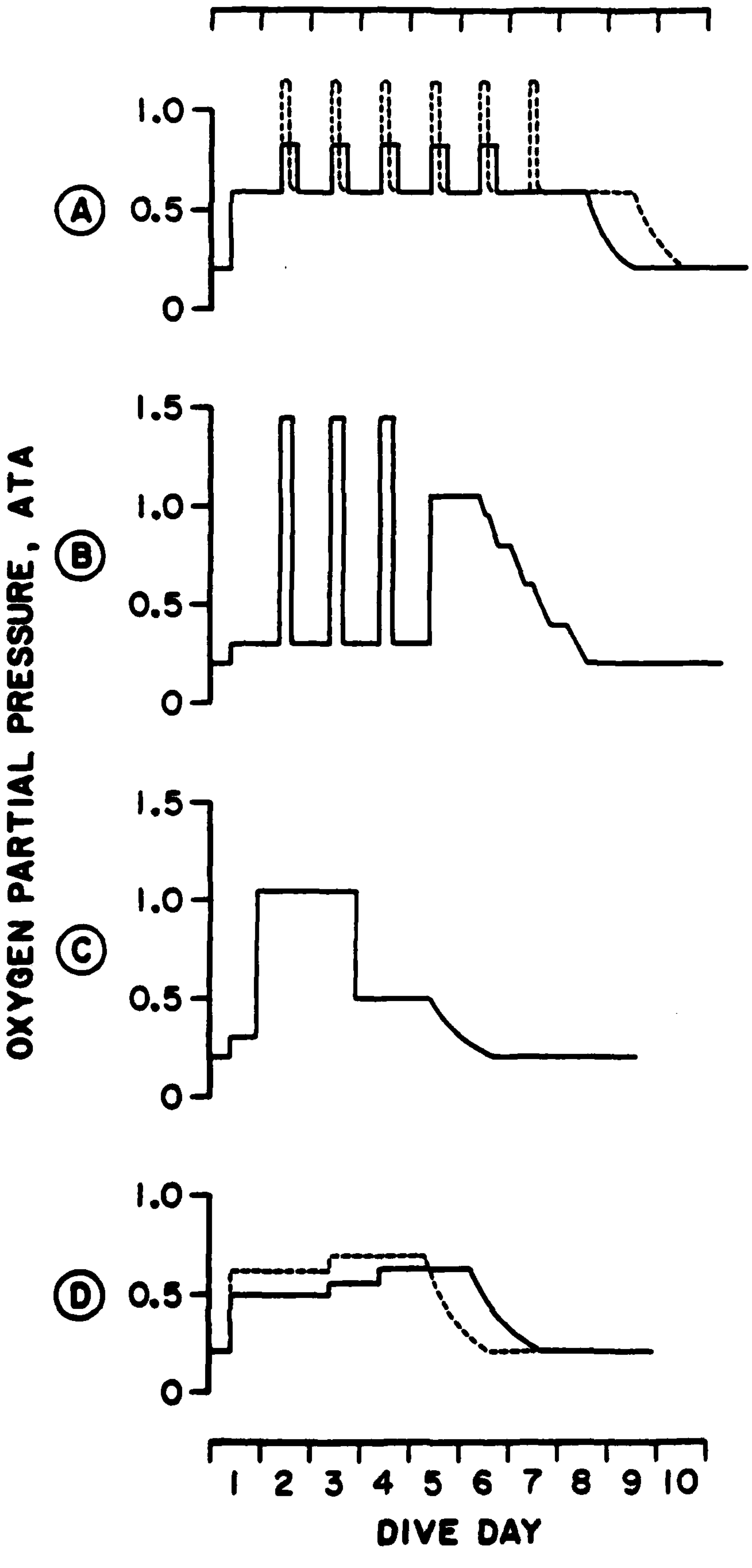
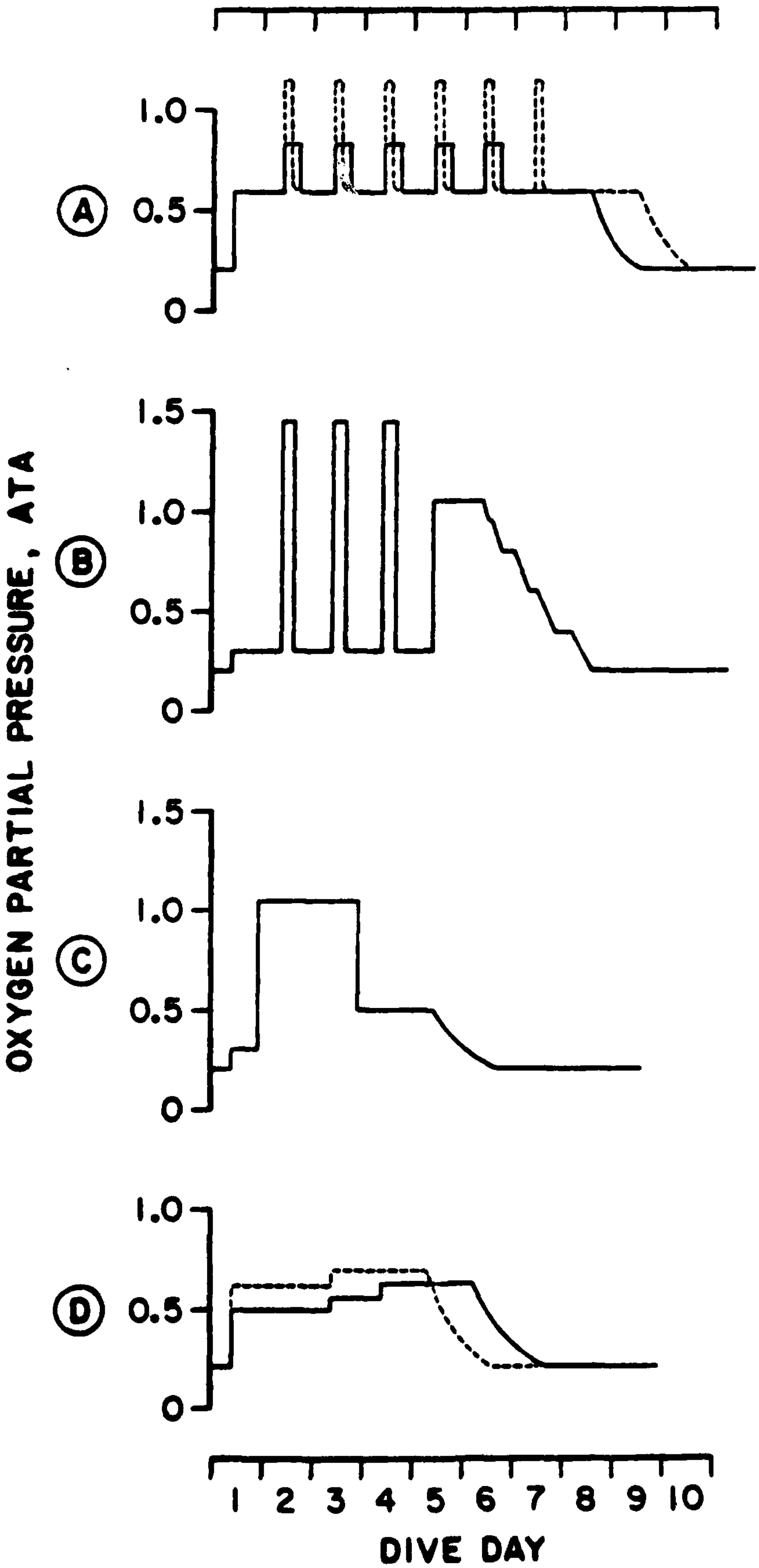


Figure 2



OXYGEN PARTIAL PRESSURE, ATA
A
1.0
0.5
0
B
1.5
1.0
0.5
0
C
1.5
1.0
0.5
0
D
1.0
0.5
0
1 2 3 4 5 6 7 8 9 10
DIVE DAY

Figure 2



OXYGEN PARTIAL PRESSURE, ATA
A
B
C
D
0
0.5
1.0
1.5
1 2 3 4 5 6 7 8 9 10
DIVE DAY

ND

ATE