Undersea Biomedical Research, Vol. 1, No. 2, June 1974

BRIEF COMMUNICATIONS

Comparison of U.S. Navy air decompression tables by gas-loading analysis

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Freitag, M., and R. W. Hamilton, Jr. 1974. Comparison of U.S. Navy air decompression tables by gas-loading analysis. Undersea Biomed. Res. 1(2):175-179.—A gas-loading comparison has been made between the U.S. Navy standard air decompression tables and the surface decompression tables using either oxygen or air. The results of these comparisons between the same depth-time schedules show that in all cases, for the compartment half-times used, the gas loadings at the end of the surface decompression with oxygen tables are less than or equal to those of the standard air decompression table. A similar comparison between the surface decompression with air schedules and the standard air tables showed 25 schedules following surface decompression using air in which at least one compartment had a final gas loading greater than the same compartment for the same depth-time schedule using the standard air tables. It seems reasonable that the repetitive procedures designed for the standard air tables can be used with surface decompression tables in all cases where surface decompression is done with oxygen and in certain cases where air is used.

decompression
decompression tables
surface decompression
gas loadings
repetitive diving

Commercial diving operators working with compressed air often prefer to use *surface decompression* techniques in preference to *standard air* decompression tables. The surface technique allows the diver to surface directly from a short or shallow air dive, or from a stop at about 30 fsw from a long or deep exposure. He (or she) then enters a decompression chamber and within certain time limitations (e.g. 5 min) is recompressed to a pressure of perhaps 40 fsw, from which point he is then decompressed. The final decompression often involves a considerable amount of oxygen breathing.

Surface decompression has many advantages over the traditional method of having the diver *hang-off* in the water. The diver is warm, dry, and safe, and work can proceed while he is decompressing. With U.S. Navy tables the decompression using oxygen has been found to cause fewer bends and take less time than the standard air tables.

Many operators stick strictly to U.S. Navy diving practice as set out in the *U.S. Navy diving manual* (1970, 1972). Under these conditions the standard air tables have one real advantage in that repetitive dives are permitted. In practice, it is generally accepted that the repetitive tables will work with the surface decompression tables using oxygen, but this practice is not specifically allowed in the Navy manual. This report describes a *theoretical* comparison of three commonly used U.S. Navy diving tables, with the intent of determining in which cases it should be possible to make repetitive dives using the repetitive schedules prepared for the standard air tables.

ANALYSIS

A comparison of the gas loadings existing at the end of decompression was made for three U.S. Navy diving tables. These tables are referred to here as standard air, surface decompression using oxygen, and surface decompression using air. Detailed references to these tables are given in Table 1.

TABLE 1
Tables covered in analysis

Although the U.S. Navy tables themselves have not changed much over the years, their designation and location is different in the different publications. This table attempts to clarify this situation.

Kind of Table	Date	Table Number	Section	Page
Standard air decompression	1972*	1-10	1.5.2	111
table (*Standard Air*)	1971†	1-10	3	61
	1970‡	1-10	1.5.2	111
	1963§	1-5	1.5.2	98
Surface decompression table	1972*	1-15	1.5.2	128
using oxygen	1971†	1-26	3	78
	1970‡	1-26	1.5.5	159
	1963§	1-17	1.5.5	121
Surface decompression table	1972*	1-16	1.5.2	131
using air	1971†	1-27	3	82
	1970‡	1-27	1.5.5	161
	1963§	1-18	1.5.5	122

* U.S. Navy diving manual. 1970, incorporating Change 1, 1972.
† U.S. Navy diving operations handbook. 1971.
‡ U.S. Navy diving manual. 1970.
§ U.S. Navy diving manual. 1963.

Analyses were performed using a computer program developed in this laboratory and not previously reported, designated Multi-Gas Analysis Program (MGAP). It produces the sum of partial pressures of inert gases in each of 13 *tissue* compartments at each discontinuity in the time-pressure profile. Half-times used in the analysis were arbitrarily chosen and are given in Table 2. Terms used here, and the relationship of *gas loadings* to decompression and decompression tables are given in detail by Schreiner and Kelley (1971) and Hamilton, Kenyon, Freitag, and Schreiner (1973).

Computer analysis was performed under the following considerations: (1) Following the U.S. Navy definition of bottom time, compression was considered to be "instantaneous." (In practice, compression time is *included* in bottom time.) (2) Decompression to the first stop and between stops was at 60 ft/min. (3) Full time was spent on the bottom and at each stop. (4) When oxygen breathing was indicated, a 2% concentration of nitrogen was assumed to be present in the inspired gas. (5) For those schedules involving surface decompression, the full time allowed for surfacing, transfer to the decompression chamber, and recompression was used in the calculations.

TABLE 2

Representative gas loadings

Compartment			1	2	3	4	5	6	7	8	9	10	11	12	13
N2 Half Time			5	9	12	15	27	35	52	89	118	155	238	413	544
Depth/T		TDT													
70/120	AIR	52	34	35	36	38	46	49	52	51	48	45	40	35	33
	SDO	32	1	9	15	21	37	43	48	47	45	43	38	33	32
	SDA	59	34	34	35	37	44	47	50	50	48	45	40	35	33
80/70	AIR	24	36	43	48	51	58	58	56	49	45	41	36	32	30
	SDO	23	5	19	28	34	47	50	49	45	42	39	35	31	29
	SDA	31	34	39	43	46	54	55	54	48	44	41	36	32	30
100/60	AIR	39	34	38	42	46	55	57	56	50	46	42	37	32	31
	SDO	30	2	13	22	29	45	48	49	45	42	39	35	31	30
	SDA	46	34	36	39	43	52	54	54	49	45	42	37	32	31
120/100	AIR	150	34	34	34	34	37	39	44	50	50	49	45	39	36
	SDO	86	0	0	2	4	18	26	38	46	46	45	41	36	34
	SDA	194	34	34	34	34	35	37	40	46	47	47	44	39	37
150/30	AIR	34	35	42	48	52	59	58	54	47	43	39	35	31	29
	SDO	30	4	19	29	36	49	50	48	43	40	37	33	30	28
	SDA	47	34	38	42	45	53	54	52	46	43	39	35	31	29
170/40	AIR	82	34	34	35	37	46	49	52	50	48	44	39	34	32
	SDO	72	0	2	7	12	30	37	44	45	43	41	37	34	31
	SDA	109	34	34	35	35	41	44	48	48	46	44	39	34	32

Theoretical gas loadings in feet of sea water (1 fsw = 1/33 atm) at completion of dive, for certain depth-time combinations. Abbreviations: TDT = total dive time, minutes; AIR = standard air tables; SDO = surface decompression using oxygen; SDA = surface decompression using air.

The gas loadings on each schedule were followed in each compartment for the duration of the dive. The loadings were printed out on arrival at the surface for the schedules in the standard air tables and on arrival at the surface following recompression for the surface decompression schedules. Comparisons were then made between the same time-depth schedules for the air and each surface decompression table. After the initial comparison the marginal points were rechecked, allowing for enough mask leakage to result in an inspired gas containing 90% oxygen and 10% nitrogen.

RESULTS

The comparisons show that for all schedules in the range 70 to 170 fsw and all compartments, the loadings in the surface decompression with oxygen were less than or equal to those in the air tables. On the other hand the gas loadings calculated from the surface decompression using air in several cases had compartmental gas loadings at least 1 fsw greater than the gas loadings calculated from the standard air schedules. These are listed in Table 3.

Representative gas loadings of the three tables are given in Table 2. This table also includes total decompression times, for comparison. Mask leakage of up to 10% nitrogen did not change any comparisons. Leaks which allow more nitrogen than this in the inspired gas may permit excessive nitrogen to be retained, and should be avoided.

TABLE 3

Schedules in which surface decompression with air causes loadings
1 fsw or more greater than the same time-depth schedule for air tables

Depth fsw	Bottom time min	Depth fsw	Bottom time min
90	120	140	40,60
100	40	150	25,60
110	60,70,80,90,100	160	40,50,70
120	70,80,90,100	180	20,25,30,50
130	50,90	190	25

CONCLUSION

The results of the analysis show that from a gas-loading viewpoint—under the limits of the half-times examined and criteria of the analysis—all surface decompression using oxygen schedules can be considered comparable to or better than the same time-depth schedule in the standard air decompression tables. This implies that the repetitive group designations (U.S. Navy 1970; p. 115-117) can be used for all the surface decompression with oxygen tables. Except for those schedules listed in Table 3, the same applies to the surface decompression using air tables, between 40 and 190 fsw.

It should be pointed out that the gas loadings in this analysis were not compared against established values—a *matrix*—but just against each other. Although some workers in diving research may not accept the physiological relevance of gas loadings in a "perfusion limited" model (e.g. Hills 1971), there is ample evidence that this approach does result in a practical method for developing decompression procedures (e.g. Hamilton et al. 1973; Schreiner and Kelley 1971).

One caution should be expressed with regard to use of the U.S. Navy repetitive procedures: where dives requiring substantial decompression are repeated on a daily basis, it is possible to encounter bends after a few days even if all procedures are followed properly. The reason for this is that these procedures consider that a surface interval longer than 12 hours enables a diver to start over and use the regular printed times, whereas such a diver may have a significant residual gas loading in the slower compartments (12 hours is only about 1½ half-times for the slow compartments). Bends under such conditions have been observed.

This work was supported in part by Harter Underwater Corporation, and in cooperation with Union Carbide Corporation, whose efforts were supported by Office of Naval Research contract N00014-74-C-0424 with funds provided by the Bureau of Medicine and Surgery.

Received for publication March 1974.

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